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A PROSPECTIVE COHORT STUDY OF MATERNAL FACTORS IN CHILDHOOD ASTHMA: PARITY, OBESITY, FETAL GROWTH, AND SOCIAL STRESSORS

A DISSERTATION

SUBMITTED TO THE GRADUATE FACULTY

in partial fulfillment of the requirements for the

degree of

DOCTOR OF PHILOSOPHY

by

KATHRYN B. HELD
Norman, Oklahoma
2000

A PROSPECTIVE COHORT STUDY OF MATERNAL FACTORS IN CHILDHOOD ASTHMA: PARITY, OBESITY, FETAL GROWTH, AND SOCIAL STRESSORS

A DISSERTATION
APPROVED FOR THE DEPARTMENT OF ANTHROPOLOGY

BY

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A dissertation represents the culmination of years of study, preparation, research, analyses, and writing. It also represents large investments in time, thought, and effort by many more people than just the one receiving the doctorate. As I write these acknowledgements—my last step before turning in the final copy of this dissertation—I realize that, at the same time I look forward to a new beginning, one of the most important chapters in my life is coming to a close. The fun part is knowing I can take what I have learned and go forward to new places and new projects. The bittersweet part is thinking about the people who have become such an important part of my life during these years of study and the deep gratitude I feel to those that made my degree and this dissertation possible.

This is a longitudinal study. That means much of the data incorporated were collected earlier, before I become involved with the project. Many of the people who conducted the original prenatal interviews I have never met. My part of this project would not have been possible without theirs.

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families I met and the conversations we had. They have changed my perspective of the world. I can only hope to do partial justice in this dissertation and subsequent writings to the mothers and children that participated in this study.

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ABSTRACT

This project uses prenatal, postnatal, and follow-up data from a prospective cohort study of 131 mother and child dyads to examine (1) risk factors for asthma in children at 4-7 years, (2) how having asthma changes the life of a child, and (3) social factors affecting the ability of mothers to manage asthma in their child. Both quantitative and ethnographic data are incorporated.

Hypotheses tested demonstrate higher asthma rates among children born asymmetrically growth retarded with smaller chest circumference or shorter trunk length for gestational age. Body mass of mothers was also higher for children diagnosed with asthma. Asthmatic children were born to younger mothers with lower parity. A prior history of elective abortions in mothers increased risk of asthma in index children. Number of people living in the home, however, did not influence asthma rates. Housing and living conditions had only a modest association with rates of diagnosed asthma. Maternal smoking did not increase risk. In fact, asthma rates were slightly lower among children whose mothers smoked during their pregnancies or at follow-up. Sociodemographic characteristics associated with higher asthma rates differed by ethnicity. Among European-Americans, children with asthma were born into families with lower household incomes and were more often born to single mothers. Among African-American children, on the other hand, those with asthma

lived in households with higher incomes and their mothers were more likely to be married.

Asthmatic children had poorer lung function, more illness episodes, and more contact with health professionals. Boys diagnosed with asthma were viewed by their mothers as less masculine. Children with an asthma diagnosis also had higher vocabulary scores as assessed by the PPVT-R. The social conditions in many low-income households made management of allergen exposure nearly impossible. Ethnographic evidence suggests fear of crime drives many parents to keep their children indoors, reducing their opportunities for exercise and increasing sustained exposure to indoor allergens.

Most of the risk factors identified in this study—maternal obesity, maternal age and parity, maternal history of prior elective abortion, and social stressors—could logically be linked to promotion of Th2-type immune function. Possible mechanisms are discussed.

CHAPTER 1
Introduction

PREVALENCE OF ASTHMA

Nearly 14 million Americans, 5.4 percent of the population, identified themselves as asthmatic in 1994. That was an increase of 75 percent over the previous fifteen years (CDC, 1998b). Asthma is truly epidemic. Increasing worldwide (Woolcock and Peat, 1997), it has become the leading cause of morbidity among children in virtually all economically developed countries. In the United States, it affects 74.7 per 1000 of the children five to fourteen years old, the highest rate of any age group. Prevalence since 1980 has soared 160 percent among preschoolers. A cohort study in Minnesota looked at the incidence of new disease rather than lifetime prevalence and demonstrated that the increase in new cases in the mid-1960s through mid-1980s was entirely among children less than fifteen years old (Yunginger et al., 1992).

Some researchers consider the possibility that the increased incidence could be caused by increased diagnosis of asthma for conditions previously counted as bronchitis, but most reject that explanation on grounds that bronchitis morbidity has not changed (Menardo and Michel, 1991). In fact, the problem is probably understated by counting only physician-diagnosed disease, especially among low-income children not covered by medical insurance. A phone survey of parents found more children with asthmatic symptoms but no formal diagnosis than with symptoms

and a diagnosis (Silver, Crain, and Weiss, 1998). Menardo and Michel (1991) report that asthma is often underevaluated. They found a serious bronchial obstruction in up to 20 percent of the patients previously diagnosed but without clinical symptoms.

Whatever accounts for the increase in asthma among children, it acts very early in life. More than 80 percent of the children aged six to seventeen with asthma have onset in the first five years of life, and the proportion is even higher—90 percent—among African-Americans. As a group, African-American children have a much greater prevalence than European-American children (Weitzman, Gortmaker, and Sobol, 1990). One estimate puts prevalence of asthma among African-American children 26 percent higher than among European-American children (Evans, 1992).

IMPACT OF ASTHMA

Even more than a decade ago, asthma was already the leading cause of school absences and accounted for 25 percent of the limitations in childhood activities (Newacheck, Halfon, and Budetti, 1986). In 1988 alone, children with asthma had 12.9 million contacts with physicians. They had 200,000 more hospitalizations and missed 10.1 million more days of school than children without asthma. Almost 30 percent of the children with asthma had some limitation in activity, compared with only 5 percent without asthma (Taylor and Newacheck, 1992). Direct and indirect costs related to asthma in 1990 were estimated at $6.2 billion (Weiss, Gergen, and Hodgson, 1992). By 1998 direct annual healthcare costs alone for asthma exceeded $6 billion (Anonymous, 1998).

ONE OF THE BIGGEST MYSTERIES IN MEDICINE

Much is understood about factors that increase the risk of asthma and exacerbate asthmatic conditions. But causes of the dramatic worldwide increase have not been fully identified. There are various theories, but no consensus. Prevalence began to increase worldwide about 1960 (Platts-Mills, 1999). Clearly, the million-dollar question is, "What changed to cause the rapid spread in asthma?"

Increasing prevalence follows the general pattern of a "disease of modernization" –higher prevalence in developed countries than in underdeveloped countries, the highest prevalence among the poor in developed countries and the rich and middle-class in underdeveloped countries. Urban populations have more asthma than rural populations, especially in less developed countries (Hijazi, Abalkhail, and Seaton, 1998; Press, 1998; Weinberg, 2000; Yemaneberhan et al., 1997; Yobo et al., 1997). The United States has one of the highest asthma rates in the world, higher in some regions than others. An estimate for different regions using standardized methods shows lifetime prevalence of asthma in North American as 16.5 versus, for example, 9.4 for Asia (Asher et al., 1998).

DO ANTHOPOLOGISTS HAVE A ROLE IN ASTHMA RESEARCH?

Pop-anthropologist Helen Fisher, in her best-selling book *The First Sex*, says women will revolutionize medicine with their more holistic approach: "[F]emale physicians are generally more interested in treating the whole patient, rather than

focusing narrowly on the symptoms of a disease. Women tend to take a broader, more contextual view of almost any issue or problem, while men are more likely to compartmentalize and focus intently on one element at a time. So it is not surprising that women have a more holistic approach . . ." (Fisher, 2000: 131). But engendered cognitive styles are not the source of divided thought in medical research. Specialization is built into the medical establishment. Fisher might argue that men created the system, but the organization of medicine into specialties is an adaptation to the limits of the human mind. No one can know everything that is known or thought about the human body. People specialize to learn a set of issues in enough depth to understand and contribute effectively. Time and an inability to integrate too many things at once limit intellectual resources. Everything learned is learned at the expense of something else. But people can see only what they know, so sometimes things get missed—things that viewed from another paradigm might be obvious.

Most research on asthma is conducted within the context of one of two specialties, respiratory medicine or immunology. Respiratory medicine focuses on the mechanics of lungs and respiration. Immunology studies allergy and the immune function. Major annual conferences for these two disciplines are separate, and few scientists are active in both arenas.

Less than a handful of anthropologists have worked on issues relating to asthma. Those few have contributed an evolutionary perspective, brought the role of families and parents into focus, and called attention to the social context in which parents make decisions about caring for children with asthma. Anthropologists that

study disease place biology in a sociocultural and behavioral context. The anthropological approach to the ecology of health spans the broader issues that underlie specific disease etiologies. Many, if not most, major causes of death can be related to ways current lifestyles differ from our evolutionary past—the past our species adapted for genetically. Health issues of this sort include obesity and overnutrition, lack of exercise, chronic social stress, and crime. The distinct paradigms of anthropology have the potential to contribute something new to the critical need for a better understanding of why so many people are developing asthma and how the disease process affects their lives.

PROJECT SYNTHESIS

This project uses prenatal, postnatal, and follow-up data from a prospective cohort study of 131 mother and child dyads to examine (1) risk factors for asthma in children at 4-7 years, (2) how having asthma changes the life of a child, and (3) social factors affecting the ability of mothers to manage asthma in their child. Both quantitative and ethnographic data are incorporated.

Hypotheses tested address maternal influences on rates of physician diagnosed asthma in children. The effects of maternal reproductive history, obesity, and age are analyzed. Birth anthropometrics and gestational age are examined relative to risk for later asthma. The relationship between social stressors in mothers and asthma in children is also looked at, as is how those social stressors differ in European-

American and African-American families. Possible underlying causal pathways for the phenomena identified are discussed.

Another set of hypotheses deals with how having asthma affects the lives of children. How much time asthmatic children play outdoors relative to nonasthmatic children, the gender role perception mothers have of their asthmatic children, and language development in children with asthma are considered. Finally, a third set of hypotheses looks ethnographically at social factors influencing the ability of low-income mothers to manage the allergen load in their homes and recognize and address the health needs of their children and how fear of crime restricts the amount of time children play outside.

The balance of evidence in the literature suggests that asthma prevalence is rising, especially among children. This study cannot explain the increase but does address several factors that increase risk of asthma in young children. Some of the phenomena explored in this study, particularly obesity and amount of time children spend indoors, are increasing at a rate very similar to the rate of asthma increase.

CHAPTER 2
Asthma Literature Review

The volume of research published in medical journals and presented at major conferences every year on asthma and related areas in immunology and lung health is staggering. Medline™ pulls up 3,489 articles on "asthma" released in 1999 and 597 articles on "asthma epidemiology". The number of articles on asthma picked up on Medline™ has increased annually, from 2,760 in 1995 to 2,978 in 1996, 3,084 in 1997, and 3,352 in 1998. The American Association of Allergy, Asthma, and Immunology, the largest international organization dedicated to immunology and allergy, provided a forum at its 2000 annual meeting in San Diego for 1,948 oral and poster papers. The 2000 annual conference of the major respiratory medicine association, the American Thoracic Society, had 6,782 scientific presentations, 1,472 of them directly addressing asthma. This high output challenges researchers trying to stay abreast of current knowledge. It certainly makes an adequate review within a single chapter difficult.

The review here concentrates on the evolutionary origin of allergic-type responses, basic etiology of asthma, and its major risk factors. The focus is primarily on childhood asthma, as this is where the increase in prevalence is greatest and is the subject of the research results that follow. Demographic characteristics of people most susceptible are also covered in this literature review.

DEFINING ASTHMA

Asthma is an extremely heterogeneous disease. It is not easily defined and has no gold standard. Formerly considered an episodic and reversible airway problem, it is better understood now as a disease that is often not limited to attacks of bronchial hyperresponsiveness but can include long-lasting inflammation of the bronchi. Research shows that many asthma patients have chronic inflammation contributing to irreversible lung damage that can be cumulative (Pearlman, 1991; Peat, Woolcock, and Cullen, 1987). Pearlman (1991) suggests that there are probably various bronchial asthmas with many common features but with causal diversity:

> Asthma varies in severity and in its clinical patterns: some patients have chronic airflow limitation, some, in turn, with marked episodic exacerbations are asymptomatic for long periods, however, with periods of severe even life threatening exacerbations which reverse rapidly or result in rapid or sudden death. Some patients seem to have completely reversible airflow limitation, whereas others have a significant irreversible component. Although a vast majority of older children and young adults with asthma have evidence of heightened IgE antibody production, and a causal relationship between sensitivity to the corresponding allergens and episodes of asthma can be demonstrated, in other patients in all age groups, asthma does not appear to be associated with allergy (1991:231-2).

Though episodic and mild asthmas are most common, clinical and functional markers cannot distinguish asthmatics that will have more severe and long-term asthma or suffer permanent damage (Menardo and Michel, 1991). Most infants and preschoolers that wheeze are reacting to viral infections and will not have asthma later, but most children with persistent asthma show the first symptoms in their preschool years. For a wheezing preschooler, immunoglobulin E (IgE) levels predict

chronicity and provide the only clue to whether the child will remain asthmatic (Businco et al., 1979; Halonen et al., 1992; Kelly et al., 1990; McNichol and Williams, 1973; Morgan and Martinez, 1992).

HOW RELIABLE ARE ESTIMATES OF ASTHMA PREVALENCE?

The primary focus of the research project presented in this dissertation is to explore phenomena that may be associated with physiological processes such as alternations in immune function. It is important to remember, though, that biomedical constructs are developed within a cultural context just like all other human efforts to understand the world. Meaning is assigned to particular constellations of symptoms and test results that are thought to logically occur together.

Some conditions, such as Attention Deficit Hyperactivity Disorder (ADHD), are new labels assigned to people that do not fit into the tightly ordered modern social structure. ADHD is meaningful for describing children that have difficulty sitting at desks for long stretches of time or learning from the methods modern teachers prefer for presenting their lessons. In another cultural setting, the behaviors of those same children might fit within excepted norms and not need to be singled out with any special label. Alzheimer's is another example of a disease fairly recently defined that labels and changes the subject's relationship to society. Cohen (1998) says of Alzheimer's that, "[T]he acceptance of the inevitability and normalcy of cognitive

decline in old age has been replaced by a disease model that, even as it challenges ageist presumptions, pigeonholes individuals as Alzheimer's victims."

Asthma, on the other hand, is not a newly reified condition but one that has been recognized through time and across cultures. Asthma has plagued mankind and been recognized as distinct at least as far back as the earliest writings on medicine (Ellul-Micallef, 1997). Ancient Greek, Roman, Egyptian, and Middle Eastern medical writings describe asthma (Carlos-Stella, 1998). Hippocrates wrote about asthma (Marketos and Ballas, 1982). The Ebers Papyrus (ca 1550 BC) refers to remedies for cough and wheezing (Cohen, 1992). The Chinese physician, Chiang Chung-Ching (142-212 AD), treated asthma with ephedra (Chan, et al., 1994).

Asthma is also well known by contemporary healers in traditional cultures. A study of traditional healers in Dar es Salaam in Tanzania found that 100 out of 106 knew the symptoms of bronchial asthma and had specific treatments for the condition (Semali and Masawe, 1985). The healers recognized several distinct types of asthma but described as basic to the condition that airways block, lungs fill with mucus, ribs get tight, and patients lose energy. The healers learned their trade by apprenticing with elders and had no formal education or contact with biomedical textbooks or professionals. Most spoke Swahili only and could not read. Although concern for asthma is ancient and cross-cultural, attention and interest to the disease has become intense in Western societies over the last couple of decades.

Rapidly increasing numbers of children are labeled as suffering from the disease of asthma. It is important to consider to what extent the change has been one

of attention, semantics, and attitude or truly a trend in the physiological functioning of some people. If there has been a physiological trend, then how much difference the changes make to functioning and quality of life should be considered, too. Being labeled with a disease alters people's lives, so such pronouncements should be made with care and generally only when intervention can reduce suffering and improve quality of life.

Biases are inherent in all research efforts. In biomedical research, the boundary line between what is a normal state and what is pathological is not clear-cut. Epidemiological studies and biomedical interventions require adoption of criteria to distinguish cases from non-cases (True, 1990). In order to make comparisons, some standard must be accepted. Biomedical reification of disease as a discrete entity provides guidelines to determine at what point intervention is appropriate. In addition, epidemiological studies cannot address which factors affect prevalence until there is a way to distinguish between what counts as a disease case from what does not.

Even once biomedical standards defining disease are set, application of the established criteria may be uneven. Prevalence figures depend with on actual prevalence in a population or sample, how often patients seek care for the condition, and how often physicians diagnose the condition (Zola, 1966). Report of symptoms depends on the awareness and perception of patients and their access to medical care. In addition, diagnostic standards may differ across cultures and change through time. Physicians differ in diagnostic skill, too. Research has shown that clinicians tend to

expect a certain percentage of patients presenting with symptoms to suffer from a particular disease. The percentage of positive cases clinicians expect differs depending on whether they are in general practice or are specialized. Sackett (1991) describes a project that demonstrated how prior generalized expectations of physicians can influence the likelihood that they will diagnosis disease in a particular patient:

> "A classic example of this problem was reported several decades ago and had to do with recommending tonsillectomy (Bakwin, 1945). Among 389 eleven-year-old school children with intact tonsils who were examined by a group of physicians, tonsillectomy was recommended for 174 (45%). The remaining 215 children, in whom tonsillectomy had not been recommended, were recycled for a second opinion (without revealing the first opinion) and tonsillectomy was recommended for 99 (46%). The remaining 116 children, who by now had been given a clean bill of tonsillar health on two separate occasions, were then examined a third time; tonsillectomy was recommended for 51 (44%) of them! For us, the most remarkable finding in this study was not the inconsistency in the diagnoses and therapeutic recommendations make by these clinicians when they repeatedly examined the same children, but the consistency in the proportion of children for whom tonsillectomy was recommended in each of the three cycles of examinations: 45%, 46%, and 44%," (Sacket et al., 1991:35).

Asthma is multidimensional in that it involves both chronic and acute reductions in lung capacity, hyperreactivity of the airways, and allergic sensitization. A variety of tests, especially peak flow, methacholine challenge, and allergy testing, can be used to diagnose these different aspects. Yet, multiple testing methods sometimes yield inconsistent results, with some tests being positive and others negative. Diagnostic classification is uncertain when different types of assessments do not agree. For example, a study of 51 adult patients found that spirometry and

methacholine test results were inconsistent in 39 percent of cases (Adelroth, Hargreave, and Ramsdale, 1986). Mismatched results from self-report questionnaires and laboratory measures of airway obstruction are common (Kesten et al., 1997).

Cut-offs must be established to turn naturally continuous phenomena, such as peak flow or immunologlobulin E levels, into discrete—usually binary positive or negative—outcomes. Many patients will have test results near the cut-off points. How borderline cases are classified can have a dramatic impact on estimates of prevalence.

Communication between patients and physicians, as in all human communication, is inexact. Communication in clinical visits can be particularly problematic (West, 1984). Short time periods are allotted for communication between the patient and physician, and the social disparity between patients and physicians can make it hard for patients to explain their symptoms and concerns fully. Patients and biomedical clinicians often use different language for describing physical phenomena as well.

It is likely that both under-diagnosis and over-diagnosis contribute to inaccuracies in prevalence statistics. Of course, the very concepts of under-diagnosis or over-diagnosis embrace a biomedical definition of disease as reflecting reality. Many studies report evidence of under-diagnosis. In one example, van Schayck and colleagues (van Schayek et al., 2000) looked at 1155 adults from the general population in the Netherlands and found that clinicians detected airflow obstruction

more often than the subjects themselves were able to recognize that they had breathing difficulties.

Some researchers have raised the question that more public attention to asthma has increased the chances parents will become concerned about respiratory function in their children and seek a diagnosis from a physician. Clinicians, too, may be more likely to label a child as asthmatic than they were in the past. If so, higher rates of physician diagnosed asthma may not reflect true physiological changes in populations through time. As concern among both clinicians and the public over rising asthma prevalence grows, the threshold for diagnosis may be dropping (Veeraraghavan and Sharma, 1998). A report found misdiagnosis of asthma by primary care physicians was common in referred patients tested by methacholine challenge in a tertiary care asthma center (Joyce, Chapman, and Kesten, 1996). The authors of this study believe attention to under-diagnosis of asthma has now led to problems with over-diagnosis.

Death is an objective outcome, but mortality records have biases, too. Mortality reflects patient compliance and the efficacy of treatment as well as actual disease prevalence. Asthma mortality has fluctuated through the years depending upon available pharmaceutical treatments as much as on prevalence and trends in disease severity. Inconsistency in how diagnoses are assigned affect mortality incidence data just as it affects estimates of prevalence. A panel review of the medical records of 103 patients with asthma listed as the primary cause of death on their death certificate decided that 43 percent of the subjects probably never had

asthma (Reid et al., 1998). However, records show that asthma mortality nearly doubled in the United States from 1978 to 1989 (Arrighi, 1995). The same trend has been found in other Western countries. A careful review of records in Denmark concluded that changes in classification or misdiagnosis do not account for the increase in asthma mortality in the 1970s and 1980s (Juel and Pederson, 1992).

Because symptom perception and awareness of certain diseases differ across cultures and social groups, particular care is needed to verify whether an actual physiological change has occurred through time. One effort to provide data on prevalence of asthma symptoms that can be compared across cultures is the International Study of Asthma and Allergies in Children (ISAAC) project. ISAAC has used both written and video questionnaires. Despite careful attention to validity and reliability issues, even the ISAAC methods have inconsistent results. Agreement between the video and written questionnaires has been low (Pizzichini, et al., 2000). ISAAC reports, therefore, compare rates derived from like questionnaires only.

The balance of evidence suggests a true change in physiological phenomena has occurred over the last several decades. All around the world increases in allergic asthma have been reported. The most compelling evidence that the increase in asthma is real comes from prospective studies that have used standardized methods through time. A comparison of identical questions asked of 1,708 married adults in Scotland 1972-1976 with 1,124 of their adult children in 1996 found reports of wheeze not labeled as asthma were 10 times more common in the 1970s than in 1996 (Upton et al., 2000). The conclusion was that there was a diagnostic bias with a trend

toward physicians more often defining wheezing as asthma. This bias, however, was only in non-atopic (non-allergic) asthma. Asthma associated with allergy, measured both by symptoms reported on the questionnaire and physician diagnosis, more than doubled in one generation and no evidence of diagnostic changes was found. Another longitudinal survey of nearly 30,000 primary school children in England between 1973 and 1986 showed increased prevalence of diagnosed asthma and symptoms in each successive annual birth cohort not attributable to changes in diagnostic fashion (Burney, Chinn, and Rona, 1990). Similarly, a survey in Aberdeen administered to parents of 2,510 children in 1964 and 3403 children in 1989 found incidence of episodes of shallow breathing doubled and diagnoses of asthma, hay fever, and eczema all more than doubled. Prevalence of wheezy children not diagnosed with asthma also increased from 7.4 to 9.6 percent (Ninan and Russell, 1992).

ETIOLOGY

A model for classifying risk factors

Asthma lends itself to a three-level etiologic model with risk factors divided into (1) host characteristics and (2) inducing and (3) perpetuating environmental elements. All three levels must be present for the disease to be manifest:

Host characteristics—what makes one person more vulnerable to developing asthma than another person. A difference in host susceptibility explains why, if two people are living side-by-side in the same environment, one may become asthmatic and the other may not. Certain host characteristics also contribute

to chronicity and severity as well as initiation of the disease. Host factors include environmental exposures and both biological/innate characteristics and social/behavioral ones, though biological processes must underlie the social processes. Some environmental exposures do their damage by creating vulnerability in the host but do not directly induce asthma. Identifying hosts tends to be the focus of epidemiological research.

Primary Inducers—agents in the host's environment that actively trigger onset of the asthma disease process. These can be irritants or allergen exposures leading to primary sensitization.

Secondary Perpetuators—continuing environmental insults that contribute to chronicity, exacerbation, or progression of the disease; triggers of ongoing or recurrent hyper-inflammatory or immune responses; secondary causes.

Unless a person is vulnerable, making him or her a potential host, inducers will not initiate the disease process. Until the disease is present, perpetuators are irrelevant. Careful classification of risk factors can help inform new hypotheses. Of course, a single environmental factor (maybe high levels of cockroach dung in the home) could be both an inducer and perpetuator. But the two levels describe different stages of the disease, and the physiological action of the cockroach dung will be different in the two stages.

The relationship between asthma and allergy

Atopy, also called allergy, is an abnormal hypersensitivity to a substance, usually a protein. Understanding the physiology of the allergic response begins with

two subgroups of white blood cells called helper T-cells and known as Th1 and Th2. (For a review see Aebischer and Stadler, 1996.) The Th1 class evokes a cellular immune response to intracellular invaders such as viruses, protozoans, and some bacteria. Th2 stimulates humoral antibodies against extracellular antigens, such as parasites and most bacteria. Molecules called cytokines mediate immune activity between cells. Either Th1 or Th2 immune reactions in the extreme can be dangerous. For example, Th1 unchecked can produce inflammation leading to septic shock. A balance is maintained because the two classes of helper T-cells are antagonistic to one another; Th1 cells inhibit Th2 activity and vice versa. Problems can arise, though, if the less appropriate type of helper T-cell dominates when a foreign invader arrives.

Th2 cells are indicative of a cascade of events that can stimulate release of various antibody types, called immunoglobulins. Presence of immunoglobulin type E (IgE) antibodies is the primary phenotypic marker for atopy, and atopy does not occur in the absence of IgE (with the exception of allergic contact dermatitis). Atopic conditions include allergic rhinitis (hay fever), eczema, hives, and anaphylaxis, as well as asthma. Asthma is the only atopic manifestation except anaphylaxis that results in a significant number of deaths. More than other atopic conditions, asthma is associated with sensitization to indoor allergens, primarily such indoor allergens as dust mites, cockroach dung, cat dander, and to an extent, dog dander. As these allergens can be airborne, they can be breathed. They are also more perennial and harder for an asthmatic person to escape than the seasonal outdoor pollens and molds that trigger allergic rhinitis.

Is asthma associated with atopy in all its manifestations? Exposure to an allergen is not necessary to trigger nighttime and exercise-induced asthma attacks. Likewise, the airways of some people have an asthmatic-like reactive response to cold. Strong emotion can also trigger hyperreactive constriction in some people (Levenson, 1979; Tal and Miklich, 1976). More adults than children have hyperreactive airways without atopy. Rackermann (1918) proposed a distinction between "intrinsic" (nonatopic) and "extrinsic" (atopic) asthma (Sears, 1997). Nevertheless, atopy is strongly predictive of persistent asthma (Dave et al., 1990), and most wheezing in children past the age of three is associated with high IgE levels. Understanding asthma trends requires addressing the relationship between asthma and atopy and allergic diseases. Examining patterns of inheritance is a helpful strategy. The Tucson Children's Respiratory Study has provided many of the clues. Here are key facts that warrant scrutiny:

(1) IgE levels in parents correlate powerfully with IgE levels in children. Various and sometimes conflicting patterns of inheritance have been identified (Dewar and Wheatley, 1996). In at least two studies, a pattern consistent with Mendelian co-dominant inheritance seemed to be operating (Martinez et al., 1994; Meyers, Bias, and Marsh, 1982). Other studies suggest more complex, polygenic heritability (Dewar and Wheatley, 1996; Meyers, Beaty, and Friedhoff, 1987).

(2) Positive allergic skin tests in parents correlate with positive allergic skin tests in children (Gray et al., 2000).

(3) IgE levels correlate powerfully with asthma in children (Burrows et al., 1995).

An Australian study showed that 90 percent of children sensitized before age three develop asthma (Peat, Salome, and Woolcock, 1990). When IgE levels are low, asthma is nearly nonexistent.

Surprisingly, however:

(4) Neither positive skin tests of sensitization nor IgE levels in parents correlate with asthma in children (Burrows et al., 1995; Edfors-Lubs, 1971; Halonen et al., 1999; Sherman et al., 1990; Sibbald et al., 1980).

And yet:

(5) Asthma in parents correlates highly with asthma in children (Burrows et al., 1995; Jenkins et al., 1993), even if the children are nonatopic (Gray et al., 2000).

Thus:

(6) There is no association between parental IgE and asthma in children unless the parents also have asthma (Burrows et al., 1995).

There is some disagreement in the literature over whether total atopic sensitization has increased or only asthma, but most researchers believe atopy is increasing (von Mutius et al., 1998; Sears, 1997; Sibbald, Rink, and D'Souza, 1990).

The way these observations on the relationship between IgE, atopy, and asthma are interpreted influences how hypotheses to account for rising asthma rates are constructed. Three opposing models have been proposed, and the questions each generated differ subtly:

(1) IgE and asthma are closely linked genetically and often inherited together, but

IgE and atopy are not direct causes of asthma (Gray et al., 2000; Martinez, 1997a; Pearce, Pekkanen, and Beasley, 1999). Inheritance of an allergic phenotype is distinct from inheritance of an asthmatic phenotype, although the two often occur together perhaps because of genetic linkage. Allergic rhinitis and eczema are both IgE-related diseases distinct from asthma, but often co-morbid with it. In fact, asthma may instead increase serum IgE levels (Rolla and Bucca, 1989). This is the scenario Martinez prefers (Martinez, 1997a).

Question: what in the environment or behavior has caused an increased expression of genes responsible for asthma?

(2) IgE levels are causal for asthma. Allergic rhinitis, eczema, and asthma are all different manifestations of the same disease. A total increase in atopy may have occurred but not at a level that can account for the asthma increase (Crater and Platts-Mills, 1998). For other allergic conditions such as allergic rhinitis ("hay fever"), there has been no increase of the magnitude of asthma, if any real increase at all. As Peat (1990) found that children sensitized very early have a high probability of manifesting asthma, it may be that what has increased is not sensitization but very early sensitization. Platts-Mills favors this model (Platts-Mills, 2000).

Question: what in the environment or behavior has caused expression of IgE-related disease to center more often on the lungs?

(3) IgE levels are causal for asthma. Allergic rhinitis, eczema, and asthma are all different manifestations of the same disease. Asthma has increased along with

a general increase in atopy. Increased allergen exposures have led to increased atopy, and because people now spend so much time indoors, more people have become atopic to the indoor allergens most likely to cause asthma (Custovic and Chapman, 1997). Sears is a major proponent of this viewpoint (Sears, 1997).

Question: what specific allergen exposures in the environment have lead to increased sensitization and atopy?

The issues are complex, and the evidence is often contradictory and always changing, as literally thousands of new studies are announced every year. Sophisticated thinkers—including those referenced here—remain flexible in their working models and recognize that there is probably some truth in all three of the above interpretations. For purposes of this study, three assumptions are made: (1) IgE-driven atopy is integral to most asthma, especially in children, (2) atopy in general is probably increasing, and (3) increase in atopy alone and increase in exposure to indoor allergens alone are not enough to account for the rise in asthma. Some other factor, or probably multiple factors, has caused more atopic individuals to develop asthma, especially children.

WHY DO HUMANS HAVE IgE AND ALLERGIES?

The large number of genes involved in atopy and asthma means redundancies are built in. And there is another implication: the genes involved are not random deleterious mutations that crop up occasionally. They are an established element of

human biology, at least at the population level. The logic of evolutionary biology dictates that a genotype as common in humans as the one responsible for atopy and asthma must have had some ancient advantage in a setting different from now. Production of IgE is the main phenotypic manifestation of genes involved in atopy. IgE exists for some reason that must be integral to human functioning and that must have promoted reproductive fitness in the past to a degree large enough for the IgE-related genes to become fixed in human populations.

The most comprehensive and compelling hypothesis for why humans beings produce IgE and suffer all the miseries of allergies is that the IgE system evolved to keep parasites in check (Barnes, Armelagos, and Morreale, 1999; Hurtado, 1999). Parasite infestations, particularly helminthic intestinal worms, were pervasive throughout the evolutionary past of humans. The second epidemiological transition associated with the rise of agriculture would have exposed humans particularly to parasites brought into their proximity by livestock. Barnes has pointed out that the use of manure and human feces as fertilizer would have established intestinal worms even further as persistent elements in human ecology (Barnes, Armelagos, and Morreale, 1999). The IgE subgroup of immunoglobulins attacks foreign proteins. The IgE antibodies become antigen-specific, dedicated to attacking only specific types of substances. It is this sensitization, the ability of IgE to specialize, that provides protection from parasites. "In studies in which parasite-specific IgE antibodies were transferred from one animal to another (*passive transfer*), and the animal receiving the antibodies was exposed to the helminth, protective immunity

was evident (Capron and Dessaint, 1985; Verwaerde et al., 1987), confirming the conclusion that IgE antibodies are capable of providing protection against parasitic infestations" (Barnes, Armelagos, and Morreale, 1999:220).

If a person is genetically capable of mounting a strong IgE response but does not have parasites, the IgE mechanism may rally against other types of foreign proteins. The proteins being attacked are often ones that would not ordinarily threaten the person. The symptoms of the IgE response itself may be much worse than the presence of an innocuous foreign protein. This hypersensitivity is what is meant by an allergic reaction. The flexibility of the IgE system gives the body the ability to adapt to whatever troublesome foreign proteins it finds invading the sanctity of self, usually through mucosa. This is why one person with high IgE levels may be sensitized to cat dander while another person with high IgE may be sensitized to ragweed. Once cat dander-specific IgE antibodies form, the person is apt to remain allergic to cats. A person may have antibodies to a single allergen or to a number of them.

There are several classes of immunoglobulins. The highest concentration in the body is of immunoglobulin type G (IgG). Every immunologically normal person produces IgG, which fights such intracellular pathogens as bacteria and viruses. On the other hand, some people can mount stronger IgE attacks than others, and many people produce low levels of IgE considered clinically insignificant. If IgE had been universally good, even in our heavily worm-infested past, most people would surely be able to mount a massive IgE defense. If IgE had no use and only tormented

people, only a few sad products of deleterious mutations would be prone to produce IgE. There would be no complicated genetic backup system with multiple genes involved in IgE production. Clearly, then, the IgE system is part of our biological adaptation and is adaptively functional under some circumstances, probably when parasites are rampant. Equally clearly, though, IgE is a system that has benefited some people more than others and carries some cost.

Does the parasite theory explain who gets asthma?

A hypothesis that the asthma epidemic is the result of fewer parasites followed by an increase in exposure to the indoor allergens most often involved in respiratory allergy is logical, but it is not sufficient. The two basic suppositions are sound: (1) that ability to produce IgE is a trait that evolved to mediate the effect of helminth infestations so lack of parasites can leave IgE available to attack other antigens; and (2) that exposures to key indoor allergens lead to primary sensitization with production of IgE antibodies that manifest in asthmatic symptoms in genetically prone people. However, this model is too simplistic to fully explain what is happening with atopy and asthma because (1) reduced helminth infestation in counties with developed economies came well before the major increase in asthma began around 1960 (Zimmermann, Steele, and Kagan, 1968), and (2) the total prevalence of such atopic conditions as asthma continues to climb. The absence of large parasite infestations is probably a necessary condition but not the proximate cause for the recent rapid increase in asthma. At least one other intervening step is

missing, something that takes people that are genetically adapted to living with helminths through genes prone to IgE production and makes them even more susceptible to becoming sensitized to particular allergens, especially allergens with a specifically respiratory action.

Though some question the protective effect of parasites on asthma (Weiss, 2000), the relationship between parasites and IgE explains asthma rates in some groups. Populations such as the Hiwi (Hurtado, Hill, and James, 1996) and Yanomamo (Lynch et al., 1983) of Venezuela that have very high parasite loads have extremely high IgE levels and virtually no asthma or other atopic diseases. Scanning broadly across continents and countries, asthma appears to be most common in developed countries with few intestinal parasites and least common in African and Asian countries most likely to have high levels of parasitic infestation.

The Falasha Jews from Ethiopia provide an excellent example of the relationship between parasites and asthma. The Falasha lived in Ethiopia until they were brought to Israel in 1984-85 and 1991. They arrived in Israel with a very low asthma rate of 2.5 (Nahmais et al., 1993)—like most rural Africans—and a high rate of helminths infection (Bentwich et al., 1996), again like most rural Africans. To prevent the transmission of intestinal parasites to other Israelis, the new immigrants were treated en masse for worms. Initially 81.3 percent had worms, but of those, 84.4 percent were cured by treatment (Nahmias et al., 1991). Now, a decade later, an alarming 17 percent of the immigrant-generation Falasha have asthma, three times more than other Israeli Jews (Rosenberg et al., 1999). Undoubtedly, with the

parasites gone or greatly reduced, the Falasha's high IgE lashed out to attack other antigens, resulting in atopic asthma.

HOST CHARACTERISTICS – WHO IS VULNERABLE

The key to understanding the rising prevalence of asthma is the factors that make people initially vulnerable. Many host characteristics influence the severity and periodicity of attacks, as well as acquisition of asthma.

Heredity

Genetic predisposition is essential to the development of an atopic or asthmatic phenotype. The three-stage etiologic model makes the artificiality of the "nature or nurture, biology or environment" question clear. Asthma, like most any non-infectious disease, requires interaction between genes and the environment. It is a truism that the body will not react to the environment to produce a given phenotype unless the necessary genetic code that provides for the reaction is present. In even the most extreme, high-risk environments, some people do not develop asthma and probably never would. A person must have certain genes before environmental insults can lead to an asthmatic phenotype. There may be genotypes that would develop into an asthmatic phenotype in almost any environment. Certainly, there have been records of asthma for centuries, as long as there have been writings about medicine (Ellul-Micallef, 1997). But there have been genotypes that did not develop asthma in past environments but do now. These are the genotypes of greatest interest.

Identifying the specific genes involved in the disease process is vital.

Numerous studies demonstrate familial patterns in allergies and asthma. Many of their key findings are listed in the section on "The relationship between asthma and allergy." Children with two asthmatic parents may have a 40 to 60 percent chance of becoming asthmatic themselves (Holgate, 1997). Studies of identical twins reared apart demonstrate the importance of inheritance (Blumenthal and Bonini, 1990; Edfors-Lubs, 1971). But that is no surprise. Although case-control studies have found that first- degree family history of atopy makes more difference than the home environment (Leen et al., 1994), the environmental elements that induce sensitization must be present. Asthma itself develops in response to the environment.

Diseases with simple Mendelian inheritance tend to be rare. In such cases, penetrance is nearly total, making the environment unimportant. Common diseases generally have complex inheritance with many genetic pathways that interact with the environment to produce varied but related disease phenotypes. Penetrance is usually less than 100 percent, so some people carry a genotype consistent with the disease without expressing the disease phenotype. Asthma genetics are complex with many genes in differing combinations capable of contributing to its expression. Given the diversity of asthma presentations, there are probably several etiological pathways that result in an asthmatic phenotype.

The nature/nurture question can bear on efforts to understand clusters of disease in subpopulations such as ethnic or social class groups. The question

becomes whether the concentration results from genetic stratification or environmental exposures and cultural behaviors. Examined at the level of population surveys, heredity and environment cannot be distinguished. Detailed studies comparing specific subgroups are especially valuable.

With asthma prevalence increasing so rapidly, more people with asthma have no family history of the disease. Familial asthma may be fundamentally different from non-familial asthma, even when disease phenotypes behave similarly. Both will have genotypes that increase vulnerability, but the genotypes are likely to be different and the environmental insults that lead them to develop an asthmatic phenotype may be different. Though asthma in parents correlates highly with asthma in children, adult and childhood asthmas have distinct characteristics. A parent with asthma may not have the same underlying pathology as the asthmatic child.

Geography

Methodological differences in studies hamper the mapping of spatial patterns of asthma prevalence around the world. Prevalence in studies cannot be compared if there are differences in the way asthma was assessed. To address this problem, the International Study of Asthma and Allergies in Childhood (ISAAC) uses a standardized survey in 56 countries. The project is only a few years old, but ISAAC data are becoming available (Asher et al., 1998).

The United States has one of the highest prevalences of asthma in the world based on ISAAC assessments, but not the highest. Australia and New Zealand have

the greatest burden, where 18.1 percent of parents reported their child wheezed in the past year. The United States has pockets with rates that high, in inner-city neighborhoods, but overall prevalence is much lower. ISAAC found 12.3 percent of the children in North American were reported to have wheezed in the previous year. Rates in Great Britain are comparable, or slightly higher (Salome, 1997). The lowest rates are in Africa (Weinberg, 2000), Asia (Zhong et al., 1990), and Eastern Europe (Asher et al., 1998). Patterns of prevalence and their probable causes differ from country to country, with significant and complex variations within countries relating to socioeconomic and ethnic clustering and differences in climate.

Demography

Much research into childhood asthma has focused on socio-demographic variables, including socioeconomic status (SES), ethnicity, sex, and family structure. These population characteristics can be generalized as significant in a large variety of diseases with differing relationships to the disease process, and they have been associated statistically with asthma. However, demographic groupings can never explain the variation in individual outcomes. Neither ethnicity, SES, family structure, nor sex in themselves describe pathways for the development of disease. Because biological processes underlie social epidemiology, the demographic patterns described in this section must be associated with genetic variation, behaviors, or environmental factors in the ecology of the disease. Comparing rates between groups provides clues to factors that may influence prevalence.

Socioeconomic status

The social pattern of asthma prevalence has changed. Asthma was once thought to be an affliction of the well-off—which is still true in some counties, especially poor ones. Some studies of adults in economically developed countries still find more asthma among people of higher socioeconomic status (SES) (Lewis et al., 1995). But particularly among children in affluent counties, prevalence is now highest among the poor (Ernst et al., 1995). This is especially true in the United States (Platts-Mills, 1999). Low family income is a major predictor of hospitalization rates for asthma (Wissow et al., 1988). In Canada, where health care is designed to be universally accessible, low-income people visit physicians more and are hospitalized more often for respiratory problems (including asthma), and their more frequent visits cannot be explained by higher prevalence (Erzen et al., 1997). Greater severity is the most likely explanation. Poorer children had worse symptoms in a random sample of 3,679 Chicago schoolchildren (Persky et al., 1998). The negative correlation between SES and asthma in children is probably even stronger than many surveys show, because researcher reliance on physician diagnosed asthma leads to under reporting among lower SES children not covered by medical insurance.

Less affluent people have more exposures to potential allergens. Lower income and less educated people are more likely to smoke and more likely to live in older houses with more cockroaches, dust mites, and mold. The older air conditioners typical of older homes provide less filtration and ventilation than newer systems. Control of dust mites can be expensive. One study of mite control measures found

that lower socio-economic parents were actually more likely than their affluent counterparts to take inexpensive steps such as removing stuffed toys from their children's rooms. But other control measures, such as using mattress covers and mite-proof pillows, were beyond the means of low-income families (Denson-Lino et al., 1993). Perhaps most important, though, underprivileged people are disproportionately exposed to poor nutrition, obesity, and psychosocial stressors. The significance of obesity is taken up later in this chapter. Social stressors are addressed in the next chapter.

Ethnicity

The Centers for Disease Control issued the statement that, "Because most associations between disease and race have no biological basis, race—as a biological concept—is not useful in public health surveillance," (CDC, 1993). The CDC reports that the United States is the only major nation where researchers routinely make group comparisons by race rather than class. The social concept of ethnic categories is preferred over pseudo-biological "racial" designations. While recognizing that as a fixed biological entity, "race" is unrealistic as a way of describing human variations, and even harmful, it is important to remember that genetic differences important to health do exist between human groups.

Generally, people of non-European descent living in western developed countries have higher prevalence than do people of European descent in the same counties (Barnes, Armelagos, and Morreale, 1999). Yet children born in England are found to have a higher risk of developing asthma than those born abroad in Asia or

the West Indies (Morrison-Smith and Cooper, 1981). Ethnic Turkish children raised in Berlin have less atopy than do other German children in Berlin (Grueber et al., 2000).

In the United States, high rates of asthma among African-Americans and Puerto Ricans raise concern. One estimate has asthma 26 percent more prevalent in African-American than European-American children (Evans, 1992). Socioeconomic status alone does not explain the difference. Having adjusted for parents' education and smoking behavior, Joseph et al. (2000) found African-American children had higher IgE levels and more airway responsiveness than European-American children (as determined by reactivity to methacholine challenge). A phone survey in an integrated and uniformly middle-class community in Michigan found the lifetime prevalence of asthma among African-American children twice as high as among their European-American counterparts (12 versus 6 percent) (Nelson et al., 1997). The question is whether the higher risk of African-Americans is totally environmental/behavioral or whether people whose ancestors came from the tropics, where there are more parasites, are genetically adapted to produce higher levels of IgE (Knopf, 2000). Asthma is uncommon in most of Africa, but parasites are common there, so lack of asthma in Africa does not mean people of African descent are not genetically prone. Evidence so far is too sparse to know.

In a mixed Hispanic neighborhood in Brooklyn, Puerto Ricans had much higher prevalence of asthma than other Hispanics living, as the authors said, "on the same streets and in the same buildings" (13.2 percent for Puerto Ricans versus 5.3

percent for other Hispanics) (Ledogar et al., 2000). Others have reported the same (Carter-Pokras and Gergen, 1993), the contrast being particularly dramatic with Mexican-Americans, who have less asthma than the overall population of the United States (Dodge, 1983; Hurtado, 1995). Differences in socioeconomic status, maternal age, or smoking in the home do not explain the higher rates of asthma among Puerto Ricans (Beckett et al., 1996). Hurtado (1999) suggests that Puerto Ricans may have more asthma than Mexican-Americans because Puerto Ricans have the most African admixture of the major Hispanic groups in the United States, whereas Mexican-Americans have the least African admixture and the most Amerindian. But that cannot be the whole story, as Puerto Ricans have higher rates of asthma than African-Americans do (Beckett et al., 1996). They may bear a double burden: Puerto Ricans also have the highest rate of hookworm infestation known among the ethnic groups in the United States (Maldonado, 1993).

Ethnic or other clusterings of disease need to be examined in detail before causal assumptions are made. The story of menthol cigarettes and lung cancer among African-Americans forms a cautionary tale. It had been recognized for a while that, per cigarettes smoked, African-Americans were more susceptible to lung cancer than European-Americans and developed other smoking-related diseases at higher rates (Boring, Squires, and Health, 1992; Cooper and Simmons, 1985). Though some assumed African-Americans were simply more vulnerable to cancer, further investigating found that more African-Americans preferred menthol cigarettes (Ahijevych and Wewers, 1993; CDC, 1990). Advertising of menthol brands had been

targeted to African-Americans through billboards and magazines. Not only do menthol cigarettes tend to be higher in tar and nicotine and to increase absorption of nicotine (Clark, Gautam, and Gerson, 1996; Wagenknecht et al., 1990), but menthol causes a cooling sensation, making smoke easier to breathe in deeper. Breathing smoke deeper causes more damage. So it turns out that a simple behavioral difference, not a biological difference, accounts for the higher risk of lung cancer and other smokers' diseases in African-Americans (Sidney, 1995). Could something of this sort be happening with asthma among African-American children and other cultural groups with high rates?

Sex

Boys have higher childhood (but not adult) asthma prevalence and morbidity than girls (Arshad, Stevens, and Hide, 1993; Luyt, Burton, and Simpson, 1993). Females tend to predominate among cases of new onset in adolescence (Venn et al., 1998) and throughout womanhood. Females also tend to have more asthmatic attacks at all ages after puberty. To illustrate, Skobeloff et al. (1992) looked at hospital admissions for asthma in several age categories. They found that in age groups up ten years, males were twice as likely as females to be admitted. In age groups eleven to twenty years, male and female admissions were nearly equal, with females predominating slightly. From ages twenty to fifty, females were three times more likely to be admitted than males. After age fifty, females were 2.5 times more likely to be hospitalized than males. After being in the hospital, women are 1.5 times more likely to report an ongoing exacerbation (Singh et al., 1999). In a Barcelona study,

males over fourteen had higher mortality than females for all respiratory causes, but asthma mortality was higher for females (Sunyer et al., 1998).

Girls and women are more likely to have seasonal rather than perennial asthma. Atopic males are more likely than atopic females to be sensitized to multiple allergens, and people sensitized to multiple allergens are more likely to manifest multiple allergic conditions and for one of the conditions to be asthma (Guerra et al., 1998).

Times of hormonal change shake up asthmatic risk and symptoms for women. Most research suggests those are times of danger for new onset or worsening of symptoms (Giamarchi, Escamilla, and Pourrut, 1989; Senna et al., 1989). No only is puberty a time of risk but also pregnancy (Weinberger et al., 1980) and during hormone replacement therapy (Lieberman et al., 1995; Troisi et al., 1995a). Yet one group reported the opposite, that symptoms of asthma are apt to improve in pregnant women (Juniper et al., 1991). Some suspect oral contraceptives may cause problems for asthmatic women or even induce asthma (Forbes, 1999; Wjst and Dold, 1997), although other studies report symptoms improving after the administration of exogenous estradiol (Chandler et al., 1997) or progesterone (Beynon, Garbett, and Barnes, 1988). Published case reports record severe and sometimes fatal or near-fatal attacks during menstruation and the premenstrual period (Barkman, 1981; Gotthardt, Clark, and Roy, 1996). Other studies demonstrate worsening symptoms during menstruation or just before (Hanley, 1981; Pauli et al., 1989; Skobeloff et al., 1996). An exception is Weinmann, et al. (1987), who found no exacerbations of asthmatic

symptoms or fluctuations in lung function after testing women throughout their menstrual cycles and reviewing their medical charts. Women with dysmenorrhea or premenstrual syndrome have more extreme worsening of their asthmatic symptoms premenstrually (Elaisson, Scherzer, and DeGraff, 1986). Oddly, though, skin-prick tests show the largest weal-and-flares midcycle, around ovulation (Kalogeromitros et al., 1995). Asthma in women has been associated with abnormalities in production and metabolism of steroid hormones (Ravelo et al., 1988). Progesterone abnormalities are particularly suspect (Tan and Lipworth, 1997; Tan et al., 1996). Clearly, hormonal changes can influence asthmatic conditions, but the relationship has not been deciphered.

Hormonal control of immune function may explain why women develop asthma and their symptoms worsen when their female reproductive hormones increase. Research on transsexuals undergoing cross-sex hormone administration shows androgens stimulate and estrogens inhibit the capacity to develop a Th1 phenotype (Giltay et al., 2000). Testosterone treatment in mice enhanced breakdown of Th2 cells and estradiol preserved Th2 (Huber, Kupperman, and Newell, 1999). Pregnancy also alters the Th1/Th2 balance (Wilder, 1998), as Th2 must dominate in a successful pregnancy (Warner et al., 1996). Normal placentas in mice produce almost exclusively Th2 cytokines, and excess Th1 can induce abortion (Braback and Hedberg, 1998; Gendron and Baines, 1988; Hill and Choi, 2000; Jenkins et al., 2000; Raghupathy et al., 1999). Needs of the fetus may have driven evolutionary adaptation for female hormones to suppress strong Th1 action. But the tradeoff is that women

are more susceptible to atopy during pregnancy.

This study involves young children, the age group in which more boys than girls are diagnosed with asthma. No strongly persuasive theories explain the higher asthma rates in little boys, other than the vague generalization of that males are more generally vulnerable than females. Research on older girls and women, though, points out that hormones as well as immunological functions influence the development of asthma and its course.

Maternal factors

What happens with infants and very young children is central to the increasing prevalence of asthma. The biggest increase in new cases of asthma has been among preadolescent children (Yunginger et al., 1992). Most children with asthma have onset before age five (Weitzman, Gortmaker, and Sobol, 1990), and most children sensitized by age three develop asthma (Peat, Salome, and Woolcock, 1990). The mother's body is the prenatal environment and the lives of preschoolers center around their mothers. Ergo, mothers are important to understanding asthma in children.

There is strong evidence for a maternal effect in early onset childhood asthma. An interesting peculiarity is that children inherit atopy and asthma more often from their mothers than from their fathers. For children five years and under, having an asthmatic mother increases the risk of asthma three times as much as having an asthmatic father (Litonjua et al., 1998). In dry Tucson, many asthmatics are sensitized to the fungus *Alternaria*. In the Tucson Children's Respiratory Study,

asthma in either parent increased the risk that a child would be sensitized to *Alternaria*. *Alternaria*-negative asthma, though, was inherited only from mothers (Halonen et al., 1999). Another paper resulting from the Tucson study compared lung function in families with and without asthmatic members and found similarities between family members in families without asthma but no pattern of inheritance. In families with asthmatic members, though, mother-child correlations of FEV_1 were statistically significant though father-child correlations were not (Holberg et al., 1998). Differential maternal genetic inheritance may be at work or the mother's immune function may affect the fetus through the uterine environment.

Average age of mothers is younger for asthmatic children, as established by numerous studies (for a review see Martinez, 1997b). An adjusted odds ratio of 2.4 for wheezing in the first year of life was found for infants with mothers younger than 21 at birth compared with those whose mothers were over thirty (Martinez et al., 1992). No clues have been reported to suggest whether the association has social or biological origins. However, lower age at menarche of their mothers also increases risk of atopy in adults (Xu et al., 2000), even after controlling for parity and maternal age at birth. The fascinating part is that a woman's own age at menarche is insignificant to her own risk. Perhaps a hormonal difference in the prenatal environment, reflected in mother's age at birth as well as age at menarche, has long-term effects.

Despite clues to biological mechanisms, familial asthma is very likely partly behavioral or environmental. The stronger association with maternal history of

asthma may relate partially to social factors. Family and child rearing styles are passed on, to some extent, from previous generations. Housekeeping styles may be similar from generation to generation. As mothers are the primary caregivers in most families, a child's family environment is usually more like that of the mother's family-of-origin than the father's. For that reason, environmental and behavioral factors that influenced the mother's health may also be in the child's home. Families already dealing with asthma in another member may also be more aware and able to recognize symptoms.

Breast feeding

Studies on breast feeding and asthma risk have had mixed results. Several studies suggest that breast feeding protects a child from developing allergy later (Chandra, 1997; Oddy et al., 1999; Wilson et al., 1998). But controlling for the mother's socioeconomic status and education level, other research projects failed to find any long-term benefit from breast feeding (Ford and Labbok, 1993). A few studies have found the oppose, that breast-fed infants were a little more likely to develop later atopy (Johnson, Ownby, and Peterson, 2000a) and asthma (Dell and To, 2000), possibly because breast feeding exposes the infant to the variety of foods in the mother's diet. Positive associations between breast feeding and allergy could be confounded, though, if mothers concerned about a family predisposition to allergy choose more often to breast feed in hopes of protecting their infants (Ford and Labbok, 1993). Furthermore, mothers that smoke can pass cotinine to their infants through breast feeding, so that infants with smoking mothers have lower cotinine

levels if they are not breast fed (Becker et al., 1999). It seems very likely that breast feeding confers some immunological protection, but that it can also introduce troublesome exposures.

Anthropometry

Fetal growth and birth weight

Barker in the United Kingdom coined the phrase "fetal programming" to focus on how fetal growth influences secular trends in disease. Heart disease, hypertension, diabetes, and certain cancers have been the primary foci of fetal programming research so far (Barker, 1998), but several papers suggest that a similar approach could shed light on the trend of dramatically increasing asthma.

Studies have been inconsistent but tend to report that lower birth weight babies are at higher risk of developing asthma later (Rasanen et al., 2000; Shaheen et al., 1999). Early exposure of immature lungs and immune systems presumably plays an important role. The large number of low birth weight (LBW) babies hampers targeting of prevention efforts. In 1997-98, LBW infants accounted for 7.6 percent of live births in the United States (Ventura et al., 2000). Studies of very low birth weight infants, particularly those put on neonatal respirators, show unequivocally higher risk for poor lung function or later asthma (Arshad, Stevens, and Hide, 1993; Greenough, Giffin, and Yuksel, 1996; McLeod et al., 1996). The effect of birth weight on broader populations has not been very strong but has aroused interest. Two things might account for the weak explanatory power of birth weight alone. The first

is that birth weight is best interpreted as relative, to the mother, siblings, or later growth (Skjaerven, Wilcox, and Russell, 1988). The second is that two dimensions, gestational age and the rate of intrauterine growth, come together to determine birth weight. As a result, studies of birth weight alone mix preterm and intrauterine growth-retarded babies when the risks for each might be different. Few epidemiological studies can separate the two, because reliable measures of gestational age are hard to come by. But a good understanding of the effects of fetal growth requires that the two be distinguished.

For predicting asthma, lower gestational age appears to be the bigger risk. Kelly et al. (1995) reported that preterm infants were more likely to become asthmatic. Rona et al. (1993) found every extra week of gestation corresponded to a 10 percent reduction in the risk of severe wheeze. This makes sense, as preterm babies have less well-developed lungs with less surfactant and more risk of respiratory distress. As surfactant develops late in fetal life, many infants born preterm do not have enough. von Mutius et al. (1993) found prematurity a bigger risk for girls. A German study linked low gestational age with sensitization to a variety of allergens (Kuehr et al., 1992). Like many areas of allergy and asthma research, though, there are exceptions. High gestational age corresponded to more atopic dermatitis in a Danish study (Olesen et al., 1997), and another project found lower prevalence of allergic rhinitis with lower gestational age (Braback and Hedberg, 1998). Both ends of the tail, being born too early or late, may increase allergic predisposition. More of the studies claiming risk for early birth have dealt with

asthma or wheeze as such, so short gestation may affect lung health as well as atopy. To explain more atopy with higher gestation, Braback et al. (1998) speculate that, "[T]he abundant amount of placenta-derived Th2 cytokines during a normal pregnancy favours the differentiation of fetal T helper cell precursors into Th2 cells, especially in individuals with an atopic propensity."

Studies on the rate of intrauterine growth and asthma have also been conflicting. Kelly et al. (1995) found that intrauterine growth retarded infants born near term were somewhat *less* likely to develop asthma later. Others have also found enhanced fetal growth carries greater risk (Beasley et al., 1999). Yet Rona et al. (1993) reported that greater birth weight for gestational age improved later lung function. Two groups identified more loops and whorls in the fingerprints of asthmatics (Jaju et al., 1986; Ozkaragoz, Atasu, and Saraclar, 1971). More whorls are markers for disproportionate fetal growth (Wheeler et al., 1998).

Although intrauterine growth retardation generally indicates a more serious maternal or fetal problem (Minior and Divon, 1998), restricted growth differs from preterm birth in that it is not sudden. It is a gradual process that gives the fetus time to adapt to reduced resources, making adjustments and essential compensations. The notion of a brain-sparing mechanism is well known, but Harding et al. (2000) found a degree of lung sparing as well. They studied placental insufficiency and growth restriction in an experimental animal model by using fetal catheterization in late gestation to restrict the placental function and induce growth restriction in sheep. Birth weight of lambs was reduced to half of normal. Demonstrated effects on the

prenatal lung included an earlier increase in fetal corticosteroids, increased cellularity with increased DNA concentration (to be expected in a less mature lung), and a thicker blood-air barrier, which could impair gas exchange. The team found lung liquid production and volume normal for body weight, lungs smaller but normal relative to body weight, and surfactant synthesis not altered. Another study, by Gagnon et al. (1999), looked at even less mature fetal sheep and found increased gene expression for surfactant production associated with the higher levels of cortisol characteristic of growth restriction. Postnatally, the growth-restricted lambs in Harding et al.'s project tolerated hypoxia better than lambs of normal weight (Harding, 2000). They had smaller lungs and more lung compliance, combined with less chest wall compliance (stiff lungs and floppy chest walls). This combination should be inefficient and could be expected to increase the work of breathing, but that was not obvious from observing the lambs. Their forced residual capacity (FRC) was not lower and actually increased for body weight. Although no difference was found in the number of alveoli per respiratory unit in fetuses, alveoli per unit postnatally was reduced profoundly along with a tendency for the alveoli to be larger. Lung diffusing capacity was lower and carbon dioxide elevated. Examination of postnatal growth-restricted animals showed normal blood glucoses and corticosteroids. In sum, Harding's group found potential problems in the lungs of their severely growth-restricted animals but also some compensations.

Other researchers have found asthmatic children or those with high IgE levels often had larger head circumference at birth (Fergusson et al., 1997; Gregory et al.,

1999; Leadbitter et al., 1999). Longer gestation, higher birth weight, and large head circumference at birth have been linked to higher IgE levels in adults (Godfrey, Barker, and Osmond, 1994). Leadbitter et al. (1999) also noted that longer birth length predicted asthma by age eleven. These birth anthropometrics must be markers for something prenatal, although authors of the various studies speculate little on what larger head circumference or birth length might mean relative to atopy or asthma. But a couple of possibilities seem worth considering. First, larger head circumference and length could reflect a weak adrenal function. Parturition is initiated by the fetal hypothalamo-pituitary-adrenal (HPA) axis (Nathanielsz, 1998). Low endocrine hierarchy in the fetus prolongs gestation (Nathalielsz, 1992:168). A fetus with a weaker HPA axis will be born later. HPA function is integral to lung development and suppression of inflammation in the lungs. Head circumference growth is much less plastic than adiposity, and long bone growth is midway between head circumference and fatness in plasticity. Larger head circumference and length at birth could be the result of longer gestation rather than faster prenatal growth, and longer gestation could result from lower HPA activity. Second, maternal smoking has been associated with increased head circumference in fetuses. Lampl et al. (2000) showed larger occipital-frontal dimensions at 32 weeks gestation in fetuses of smoking mothers.

Childhood growth

Childhood asthma has been associated with less weight and height for age and delayed sexual maturity (Russell, 1994). The direction of the relationship is unclear.

Asthma may retard growth, or smaller children—with small lungs—may be more likely to become asthmatic. Because the exact time of onset of the disease is hard to pinpoint, examining growth in asthmatic children is not likely to be much help in finding the cause of the disease. Studies of how asthma alters growth need to exclude children taking steroids. Not all studies have found slower growth in asthmatic children (Power and Manor, 1995). Klein et al. (1991) gathered dietary data as well as growth parameters and found that asthmatic children were not only no smaller for their age but that those over age seven exceeded recommended daily caloric intake and the caloric intake of non-asthmatic controls.

Obesity

A handful of studies suggests that body mass correlates with asthma risk. Prevalence of obesity is higher among asthmatic adults and older children (Chen et al., 1999; Gennuso et al., 1998; Huang, Shiao, and Chou, 1999; Luder, Melnik, and DiMaio, 1998; Shaheen et al., 1999). These studies must be interpreted with care, however, because they are cross-sectional and steroid asthma medications cause some people to put on weight.

In a longitudinal analysis of over 85,000 women from the Nurses Health Study II, Camargo and colleagues found that obesity often precedes asthma both in women and in older children (Camargo et al., 1999). The same pattern applied to the nurses' children nine to sixteen years old (Camargo et al., 1999). Critics note that it is hard to be sure that obesity came first, because asthma could be present at a subclinical level long before physicians or patients are aware of a problem. People

with very early asthma might tend to be less active and therefore gain weight even though they were unaware of their respiratory deficiency. Nevertheless, the magnitude of effects in Camargo et. al's studies were large and highly statistically significant. Interestingly, the strongest predictor for women was the weight they gained after age eighteen.

A possible link between obesity and asthma is gaining attention among asthma epidemiologists, partly because obesity is growing at rates similar to asthma. The causal link is not clearly established, however. Obesity might be a risk factor itself or it might be a marker for something else. Because weight gain comes primarily from too many calories consumed for the calories burned, either diet or activity levels might be the true source of risk.

Diet

Westernized countries have the most asthma, and the cause could be the western diet (Weiss, 1997). Children of Asian origin in the United Kingdom had less bronchial hyperreactivity but more atopy than did ethnically English children. After controlling for several potential confounders, including duration of residence in the U.K., risk of hyperreactivity in Asian children had a dose-response relationship with degree of westernization of their diets (Carey et al., 1996).

Which particular elements of modern, western diets are troublesome have not been determined, at least conclusively. Many culprits are possible. Abundant food is readily available to most people in developed economies, even the poor. Klein et al.'s (1991) found that asthmatic children age seven years and older consumed more

total calories than controls. That finding is interesting in light of the research on obesity and asthma. Restricting calories in mice suppresses immunoglobulin production (Jolly et al., 1999). High consumption of salt is also implicated (Antonios and MacGregor, 1995; Demissie and Ernst, 1994; MacGregor, 1997; Matthews and Pegge, 1997). For men, a moderate reduction in salt intake corresponded to improved asthma symptoms (Carey, Locke, and Cooksen, 1993).

Micronutrient deficiencies could contribute to the problem. Lack of vitamin C (Britton et al., 1995), manganese (Soutar, Seaton, and Brown, 1997), magnesium (Baker et al., 1999; Durlach, 1995), vitamin A (Morabia et al., 1990), or selenium (Kadrabova et al., 1996) have been investigated and all found to correlate with asthma or reduced lung function or bronchial hyperresponsiveness. Zinc deficiency can lead to transition from Th1 to the Th2 immune profile that can include IgE (Sprietsma, 1999). Reviews conclude that data are insufficient to recommend dietary supplementation of any of these micronutrients for treating asthma (Monteleone and Sherman, 1997; Smit, Grievink, and Tabak, 1999).

The most intriguing suggestion on diet may be that the type of polyunsaturated fat we eat affects asthma. Part of the inspiration for this hypothesis comes from the extremely low prevalence of asthma among the Inuit (Hemmelgarn and Ernst, 1997), despite astoundingly high smoking rates, even among children. The Inuit, of course, eat a lot of fresh fish. Hodge et al. (1996) showed the risk of asthma reduced among children with diets high in n-3 fatty acids from oily fish. The corollary is that n-6 fatty acids, the polyunsaturated fats from plant sources, could be

deleterious (Hodge, Peat, and Salome, 1994). Others failed to find a benefit for adults eating fatty fish (Troisi et al., 1995b). If fats make a difference, again the reason relates to tipping the scale of immune cell type. In mice, caloric restriction and fish oil both arrested the progressive increase in Th2-type cytokines normally seen in aging (Jolly and Fernandes, 1999). Monounsaturated fats and n-3 fatty acids suppress and n-6 vegetable oils promote interleukin-1, a cytokine precursor (Grimble, 1998).

Activity levels

The increase in the time people spend indoors may be a problem because it increases exposure to indoor allergens, but not for that reason alone. Sedentariness itself may be a risk for asthma (Platts-Mills, 1997). Two experiments suggest that proper lung function requires the smooth muscles in the airway be stretched. When inspirations were restricted, nonasthmatic as well as asthmatic subjects manifested hyperresponse to methacholine challenge. After restrictions on inspiration were removed, both groups continued to respond abnormally to methacholine. In other words, restricting airway smooth muscles made nonasthmatic people respond like asthmatics (Skloot, Permutt, and Togias, 1995). Another paper posits that lack of lung inflation allows the airway smooth muscles to freeze into a static shortened equilibrium, whereas stretching facilitates maintenance of a dynamic state where muscles lengthen more easily (Fredberg et al., 1999). So breathing deeply, as people do when they are active, is essential to lung function.

Here again, immune function may come into play. In an experiment on the affects of exercise, blood was drawn from men and women before, during, and after

cycling workouts. Although the effect lasted only during activity, exercise induced production of more Th1-type cytokines (Moyna et al., 1996).

Chemical exposures

Air pollution

Mention of air pollution is warranted because many people think bad air from industrial and automobile hydrocarbon emissions has brought on the asthma epidemic. Air pollution is a problem for some people and can exacerbate asthmatic symptoms, but it has not panned out as an explanation for the increase in asthma. Air quality has improved in the United States over the last couple of decades following stricter Environmental Protection Agency regulations. And although air pollution can exacerbate symptoms for people that already have asthma, Asia, the continent with the most air pollution, has a comparatively low prevalence of asthma.

The fall of the Iron Curtain presented the opportunity for a natural experiment in East and West Germany. Asthma and atopy were compared in the formerly separated but ethnically similar countries. The initial assumption was that asthma would be more prevalent in East Germany, where air pollutants like sulfur dioxide and particulates were much higher (Nowak, Wichmann, and Magnussen, 1998). Non-allergic respiratory symptoms were higher in the east, but atopy, asthma, and bronchial hyperresponsiveness were much higher in the wealthier west (von Mutius et al., 1994a). The contrast is found generally throughout Eastern and Western Europe (Bjorksten, 1996). But differences in atopy (von Mutius et al., 1998) and bronchial

hyperresponsiveness (Richter et al., 2000) between the two regions are converging as rates of prevalence have risen in the east. Various possible causes for higher rates in the west have been hypothesized—such as more pets and dust mites, tighter housing, and less use of daycare—but air pollution can be eliminated as a major cause of epidemic asthma rates in modern populations.

Tobacco smoke

Second-hand tobacco smoke and mothers' smoking prenatally influence lung health in children (Gold, 2000). Early wheezing is more common among children with mothers that smoke. The association is stronger with mothers than other members of the family that smoke, perhaps because mothers are more likely to smoke around their children or because maternal smoking during pregnancy has been associated with increased cord IgE levels (Arshad, Stevens, and Hide, 1993). A longitudinal study using a mixed-effects model found that maternal prenatal smoking was associated with wheeze up to age three, though postnatal smoking was not (Stein et al., 1999). Children of mothers that smoked ten or more cigarettes a day and had no more than a high school education were 2.5 times more likely to have early asthma symptoms (Martinez, Cline, and Burrows, 1992). No relationship was found in children with better educated mothers.

Curiously, though, more than one study has found that the long-term outcome is better for wheezing children with mothers that smoke than for those with mothers that do not smoke (von Mutius et al., 1994b; Strachan, Butland, and Anderson, 1996). Studies even found the rate of sensitization less among children of smoking mothers,

regardless of wheeze. The effect of maternal smoking on allergic wheeze disappears by age four (Tariq et al., 1998). So children of smokers wheeze but may be less likely to have the underlying atopy that contributes to more severe and persistent asthma.

Passive smoke may not cause long-term asthma, but it definitely exacerbates the symptoms of children with atopic asthma (Martinez, Cline, and Burrows, 1992). Severity and frequency of attacks are greater for children that live with tobacco smoke in their environments (Evans et al., 1987; Murray and Morrison, 1989).

The hygiene hypothesis: do we need more exposure or less?

McKeown (1979) argued that better hygiene and sanitation have contributed more to life expectancy and health than biomedicine. If improved hygiene has reduced the effect of some diseases, it may have also contributed to others. More and more, researchers suspect that less of certain environmental exposures early in life leave a child's developing immune system unprimed and, in a sense, searching to respond to something. The child's body then becomes sensitized to allergens that should be harmless. This is an evolutionary argument. Throughout most of evolutionary history, humans lived in close contact with soil and animals, bacteria, and parasitic worms. Our immune systems are adapted to protect us from these elements. Alternatively, early exposure to certain elements may immunize against future overreaction to those elements. The idea that the modern environment is too clean for proper immune development is known as the "hygiene hypothesis."

Animals

People think they are allergic to animal hair, but the allergen is produced by sebaceous glands in the skin of furry animals. The sticky allergen clings to hair and skin and is spread as the animal sheds.

Several scientists say that having a cat or dog in the home is protective. Others disagree, stating vehemently that humans should never live with animals. A few recent studies show that infants with pets in the house, particularly cats and dogs, have lower chances of developing allergy or asthma later (Burr et al., 1994; Hesselmar et al., 1999; Johnson, Ownby, and Peterson, 2000b). Both Hesselmar et al. (Hesselmar et al., 1999) and Burr et al. (Burr et al., 1994) found cats had a protective effect in Sweden, a cold dry country where pets are the most important allergen for asthmatics (Plaschke et al., 1999). Hesselmar et al. (Hesselmar et al., 1999) controlled for the confounding possibility that parents with a history of allergies or asthma avoid owning a cat, which might leave less genetic predisposition among cat owners.

But there is as much research, or more, that makes pet ownership look deleterious. In a British project, a cat in the home increased chances of an infant having a positive skin prick test for cat allergen (Arshad, 1991). Lockey, former president of the American Academy of Allergy, Asthma, and Immunology, reported on a patient with a life-threatening allergic reaction to his pet ferret (Lockey et al., 2000). Lockey told the press (Anonymous, 2000), "We've told people that smoking is very hazardous. In the same way, animals don't belong in homes, period. I really

believe that."

Viral and bacterial infections

Mortality from infectious disease nearly disappeared in the United States by the 1950s. The decline began not long after the turn of the century as attention to allergy and specialization in allergy medicine increased. Some suspect the modern lack of infectious diseases leaves developing immune systems more vulnerable to atopy and asthma (Cookson and Moffatt, 1997).

Infections during infancy may promote a Th1 response and reduce Th2 (Holt and Sly, 1997). Measles (Shaheen, Aaby, and Hall, 1996) and exposure to tuberculosis (Shirakawa et al., 1997) have been associated with less asthma. Young adults with antibodies against hepatitis A have less atopy (Matricardi et al., 1997). Some even think that exposure to common viruses in daycare can be protective (Ball et al., 2000; Infante-Rivard, 1993; von Mutius et al., 1994b). Bacteria may be beneficial, too. Infants not sensitized to major household or food allergens live in homes with higher levels of endotoxin, the outer shell bacteria shed when they die (Gereda et al., 2000). Vaccinations may also contribute to development of an inappropriate immune profile. Asthma has been linked to diphtheria/pertussis/tetanus (DPT) and polio vaccinations and pertussis (whooping cough) vaccination alone (Kemp et al., 1997; Odent, Culpin, and Kimmel, 1994). DPT vaccination elicits a persistent Th2 response (Rowe et al., 2000).

Others claim the opposite, that viral respiratory infections trigger for the onset of asthma (Gbadero et al., 1995; Pattemore, Johnston, and Bardin, 1992).

Urbanization, rising population, and increasing use of daycare mean that people find themselves more often in groups, which may be especially a problem for small children. Children in Oslo that attended daycare had more respiratory tract infections, and children with more respiratory tract infections had more asthma (Nystad, Skrondal, and Magnus, 1999). Direct association between daycare and asthma was positive though weak. Whether infection protects or predisposes for atopy and asthma may depend on the type of infection. Among children and infants that had respiratory syncytial virus (RSV), those that developed bronchiolitis more often had allergic asthma later (Stannegard et al., 1997). Unlike many infectious diseases, RSV initiates a Th2 reaction. Still another possibility is that early infections do not cause later asthma, but infants and preschoolers already predisposed to wheeze will wheeze during lower respiratory infections. A temporary wheezing response to infection could be simply a marker for a wheezing phenotype (Martinez, 1995). Only children with a marked increase in IgE during lower respiratory infections will continue to have wheezing episodes after their preschool years (Martinez et al., 1998).

Birth order

The number of children in a family when a baby is born has been taken as a surrogate measure of viral exposure. Numerous articles report higher birth order conferring protection from allergy or asthma (Ball et al., 2000; Bodner, Godden, and Seaton, 1998; Braback and Hedberg, 1998; Lewis and Britton, 1998; Ponsonby et al., 1998; Rona, Duran-Tauleria, and Chinn, 1997; Svanes et al., 1999). None of these papers consider the possibility that there could be something protective about more

fertile mothers.

Evaluating the hygiene paradigm

Does our hygienic modern environment leave children more vulnerable to allergy and asthma? Or do we blame more exposure to infections through urban crowding? Does the problem lie with increasing use of antibiotics and vaccinations? Does exposure to large families help develop immune function?

The hygiene hypothesis in most forms comes down to this: certain exposures may stimulate development of a Th1 phenotype that is less vulnerable to asthma. Most of the exposures touted as beneficial are not allergens, the very curious exception being cats. A cat in the home during infancy may be protective. But it is hard to recommend that new parents keep a cat. If the prophylaxis fails and the child becomes atopic or asthmatic, the cat would become a risk factor for exacerbating the condition. If a preschooler already has asthma, a cat in the home increases the risk of the disease becoming severe (Johnson, Ownby, and Peterson, 2000b).

The notion that a too-clean environment leads to asthma does not fit the broad demographic picture. Asthma prevalence in the United States is highest and increasing fastest in inner cities, among the poor, among children living in crowded conditions that lead to virus exposure. Most of even the poorest children are vaccinated against measles. Neither do they have parasites or exposure to tuberculosis. But the lack of those exposures does not explain why poor children have more asthma than middle-class children.

Findings cited by proponents of the hygiene hypothesis may be part of the

story of why asthma has increased. But a broader picture would show all the modern changes in lifestyle that contributed to the diminution of Th1-type immune activity and promotion of Th2-type and IgE. Less exposure to infectious diseases is likely to be but one piece of the puzzle.

PRIMARY RISK FACTORS – WHAT INDUCES ASTHMA

If asthma is an allergic disease (associated with an allergy in most cases), the disease process is initiated by sensitization and sensitization follows exposure to a potential allergen. The biggest increase has been in perennial asthma characterized by sensitization to indoor allergens (Platts-Mills and Wheatley, 1996). By contrast, allergic rhinitis (hay fever) is associated with outdoor allergens (Platts-Mills, Wheatley, and Aalberse, 1998). That makes cockroach dung, dust mite, and cat the prime inducers of asthma.

Specific antigens people become sensitized to do not explain the increase in asthma. Although there is limited evidence for inheritance of some allergen-specific IgE antibodies (Townley et al., 1980), asthmatics in different regions are sensitized to whatever is most available in that environment. In warm, damp climates, dust mites or cockroaches are the most important allergens. In cold, dry places with few dust mites, cat is more important. Repeated exposure to allergens in infancy and early childhood is a major risk factor for later sensitization (Wahn et al., 1997). For genetically vulnerable children, there may be a dose-response relationship between allergen exposure and sensitization (Platts-Mills, 1997); but there is none between

allergen exposure and asthma (Ronmark et al., 1999). Measurement of allergen concentration in low-income inner city homes in Atlanta found high levels of dust mite and cockroach allergens in 86 percent of homes (Call et al., 1992). The asthmatic and control children living in these homes differed in their rates of sensitization to dust mite and cockroach but not in allergen exposure. A similar lack of correlation between allergen concentration and asthma was found in the homes of 88 symptomatic and 123 control middle-school children in Virginia (Squillace et al., 1997). High levels of such potential allergens as dust mite in the living environment do not induce atopy in most people (Platts-Mills and deWeck, 1989; Sporik et al., 1990).

So asthmatic sensitization is opportunistic. It is as if the body goes looking for something to be sensitized to and finds the allergen most prevalent in its environment. The allergen itself, then, is not the determinant of whether a person becomes sensitized. Platts-Mills et al. (2000) say "there is no simple relationship between allergen exposure and asthma." Seaton et al. (Seaton, Godden, and Brown, 1994) agree that increased exposure to sensitizing agents is not the problem. It is that more people have become susceptible when exposed.

SECONDARY RISK FACTORS – WHAT PERPETUATES ASTHMA

Allergen exposure may not determine who develops asthma, but further exposure to allergens after onset of the disease is important to the severity of symptoms. Dust mite droppings are the single most important allergen for asthma

(Kuehr et al., 1995; Sporik and Platts-Mills, 1992). Except in very cold or dry regions, the eight-legged arthropods live along with people in most parts of the world. Fabrics, mattresses and stuffed furniture, carpets, and other soft objects harbor dust mites and their food, the scales that slough off of human skin. Humidity in the home provides an ideal climate for proliferation of dust mites. Other allergens or irritants that exacerbate asthma include cockroach dung (Platts-Mills et al., 1991), pet dander, and passive cigarette smoke (Dold et al., 1992; Evans et al., 1987; Martinez, Cline, and Burrows, 1992; Murray and Morrison, 1989).

Structural elements of the physical living environment affect allergen load. Carpeting instead of hard floors (Zock et al., 1994) and innerspring mattresses (Flannery et al., 1994) are examples of things that harbor dust mites in the home. Tighter housing reduces air filtration. As noted earlier, people with low incomes are more likely to smoke and more likely to live in older housing where older air conditioning provides less air filtration and ventilation. The air is more stagnant in houses built tight for energy efficiency, such as were common in the 1970s and 1980s. The influence of allergens and irritants in homes is then mediated by the time a child spends indoors (Platts-Mills, 1994). Television and computers have received the blame for children spending most of their time indoors (Platts-Mills, 1997).

The situation can be improved. Steps can be taken to reduce the concentration of dust mites in a home. Structural changes, such as removing carpeting, overstuffed furniture, and plush animals make a big difference. Washing bedding in hot water weekly and putting allergen-barrier covers on pillows and mattresses help. Vanlaar et

al. (2000) reduced dust mite levels in homes 30 percent by washing bedding weekly in hot water with benzyl benzoate, a dust mite killer. As a further measure, carpeting can be sprayed every couple of months with a tannic acid solution. Intense house cleaning can reduce symptoms as much as 65 percent (Kato et al., 1991; Mazon et al., 1994).

Dust mite and cockroach allergens may be so plentiful in some low-income housing (Call et al., 1992) that such measures as frequent washing of bedding and vacuuming may have little discernible effect on symptoms. Parents may see the marginal benefit of spending scarce time and resources reducing household allergens as too low. Although they may be aware that allergens exacerbate the condition and that reducing allergens might improve the outcome for their child, they may lack the resources to make major household changes (Denson-Lino et al., 1993).

IN SUMMARY

No one knows why asthma rates continue to rise. It is one of the biggest mysteries in medicine. Several theories have been offered. Everyone in asthma research favors one notion or another, but there is remarkably little agreement on any one theory. As shown in the section on "The relationship between asthma and allergy," there is no consensus on the paradigm to be used in developing hypotheses.

Something about a modern, urban life promotes asthma by making hosts more susceptible. Improvements in hygiene, including the reduction in infectious diseases and the increase in vaccinations, obesity, diet, and sedentism, have all been

implicated. Clues from some recent studies suggest what would unify all these factors is that they shift immune functioning toward the Th2 mode. Their importance revolves around proliferation of Th2-type cytokine activity in the absence of parasites. Activation of the Th2 mechanisms can release IgE production in people genetically prone to high IgE responses.

Still, IgE leads directly only to sensitization, the beginning of several allergic diseases, of which asthma is only one. So why the increase in asthma specifically? Which antigens a person becomes sensitized to make a difference in how symptoms are manifest. People with allergic rhinitis are apt to be sensitized to outdoor pollens and molds. The indoor arthropod and animal allergens lead to asthma. Therefore, the time spent indoors probably contributes to asthma.

But there is no dose-response between exposure to indoor allergens and asthma; so, something is still missing. One possibility included in the literature is that lifestyle affects lung mechanics, making allergic disease more likely to center on the lungs. The research showing that restricting inhalation can induce temporary asthma-like reactions brings up the possibility that sedentary people have more vulnerable lungs.

This project pulls together biomedical issues with biosocial and sociocultural theory. Clearly, many of the issues addressed in this chapter are social and behavioral as well as biological. Because the literature on all these areas is so vast, the literature review is divided into two chapters. This chapter has concentrated on the biomedical literature. The next chapter deals with biosocial and sociocultural literature on

asthma, parenting, and family functioning. Look to the end of Chapter 3 for a brief synopsis of the major biosocial issues in asthma epidemiology.

CHAPTER 3
Social and Family Context of Childhood Asthma, Literature and Theory

Given what is known so far about causes and risk factors for asthma, it is clear that rising asthma prevalence is not a biomedical issue. It is a biosocial one. The age when women begin having children, what mothers eat themselves and feed their children, how active people are and how much time they spend indoors, and the condition of housing and ability to keep houses clean are all sociocultural issues. These are the things that lead to differences in asthma rates. There are large cultural or sociocultural forces determining all these behaviors that intersect with immune function and asthma rates. Why do some women begin having children early and other wait until much later in their lives? What underlies increasing obesity? Why do people stay indoors more now than they did a generation ago? These are all major sociocultural issues.

The prior chapter reviewed literature on major biomedical issues in asthma epidemiology. But there is another, equally important, aspect to explore in understanding childhood asthma—the social context. The social environment of people's lives shapes their experience with disease. For young children, their family dominates their world, and a child develops and lives with asthma within a family environment. A child's primary caretakers, the adults with responsibility for

managing the child's life, make decisions for the child and shape the living environment. In most families the mother fills that role.

THE JOINING OF EMOTION AND PHYSIOLOGY

Hans Selye first demonstrated the physiological effects of psychological stressors on laboratory mice (Selye, 1956). Essentially, a stressor is something that places an excessive environmental demand on the body while stress is the physiological reaction in which the body tries to mobilizes resources to adapt to that threat while maintaining homeostasis. The primary mechanisms of stress response are the sympathetic or parasympathetic nervous systems. Our evolved adaptation is probably for the sudden, temporary fight-or-flight responses necessary for immediate survival in the predator-prey ecology of our prehistoric ancestors, as first described by Walter Cannon (1929).

More recently, since the discovery of the Th1-Th2 system, it has become evident that psychological stressors alter immune functioning. Glucocorticoids and catecholamines, produced by activation of the sympathetic nervous system, suppress Th1-type cellular immunity and by default promote Th2, thereby changing the balance between the two types of immune processes (Elenkov and Chrousos, 1999; Nagatomi et al., 2000). Most human experiments have used short-term stressful situations, such as taking exams, to measure how psychological stress affects immune function (Kang, Coe, and McCarthy, 1996). Pessimism associates with poor immune function (Byrnes et al., 1998). Less stable home environments may also increase

immunological vulnerability. The same stress hormones and catecholamines are produced, no matter the stressor. Emotional and family stressors can be expected to initiate the cascade that pushes the immune system toward Th2 just as much as sudden extreme physical effort would.

> "The discovery of neuro-mediators and cytokines and their receptors shared by the central nervous system and the immune system has prompted research work using reliable methodologies to study the relationship between a 'hard' scientific field, such as immunology, and a 'soft' one, such as the behavioral sciences," (Vuitton, Wazieres, and Dupond, 1999).

A biopsychosocial approach to treating asthma that included attention to the psychological and emotional needs as well as physical needs of hospital inpatients showed that after only three months of treatment, 80 percent of patients had improved condition that lasted at least two to three years (Teshima et al., 1991). Of those whose asthma had been hard to manage, 45 percent were able to withdraw from steroid hormones. The connection between emotion and the nervous system and immune function is powerful. It is, almost certainly, the basis of shamanistic healing and why traditional medical practices that emphasize social connectedness and emotional support work and truly heal.

THE DEMANDS OF ASTHMA MANAGEMENT

The determination of whether disease is present is made by a clinician but relies heavily on the sickness experience of the patient and family (Armelagos, Goodman, and Jacobs, 1978; Riley, 1987). Patients or, for young children, parents of patients, become aware of illness and bring their illness complaints to a clinician

(Kleinman, 1988:5-6). Disease is the more scientific label that reflects theoretical understanding of the causes of illness. Much of the morbidity reported for young children will reflect the sickness beliefs and coping behavior of their caregivers, in most cases, their mothers. Children develop asthma within a family context. Environment and behaviors of parents, starting even before a child is born or maybe even conceived, impact the child's physiology, including immune functioning. As an example, Abell et al. (1991) have shown that family functioning prenatally is a determinant of fetal growth. Then, a child will not be labeled as asthmatic unless outward symptoms are manifest and a parent notices those symptoms. The parents must have enough awareness and concern to take the child to a physician. The physician evaluates the child and conducts certain tests, usually lung function tests and maybe allergy tests, and then deems whether a pronouncement of asthma is appropriate.

Discussion of parental investment in controlling childhood asthma should start with looking at the particular characteristics of asthma. Asthma is more a chronic than acute disease, and it is more than an annoyance or discomfort. It does damage the lungs over time and that damage is cumulative, thus efforts to control the disease are important for a child's future. Acute attacks occur, but astmatics usually have reduced peak flow all the time. The disease can last many years or a lifetime. Commitment to controlling the disease is long-term, unrelenting, and increasingly challenging the more severe the disease. Symptoms, medications, and the living environment need to be monitored. When the patient is a child, the primary care

giver, usually the mother, has responsibility for managing disease control efforts. The burden on mothers can be considerable, and not all mothers have the resources or motivation to do everything that would be recommended by an allergist.

The family response to asthma influences the sick child's outcome. As asthma and atopy run in families, a substantial proportion of newly diagnosed asthmatic children already live in families familiar with the condition. With prevalence increasing, though, many children with asthma live in families that have no prior experience with the disease.

Understanding the determinants of the extent to which mothers meet all recommendations for controlling their children's asthma requires looking at the relationship between the mother and child and the context of that relationship. Characteristics necessary for a family to be able to meet the special health maintenance needs of an asthmatic child are: (1) empathy of the mother for the child, (2) good communication between parents and children, (3) knowledge of what steps are likely to help, and (4) ability to control the residential environment and manage medications.

The asthmatic child is the best interpreter of his or her symptoms, as severity of symptoms is usually very hard to recognize for another person without the benefit of medical equipment. American parents in general do encourage verbal ability in their children. "Compared to parents in other cultures, American parents are extreme in their emphasis on verbal stimulation," (Small, 1998:106). Less educated parents, however, may have a harder time communicating with their children about asthma

(Clark et al., 1990). To effectively manage asthma in a child, the parent needs to be able to communicate well with the child about symptoms and monitor health status. The better parents and children communicate, the better asthma is controlled. Interestingly, Clark et al. (1990) found that children of Spanish-speaking parents in the United States were found to have better communication with their children about asthma symptoms. The balance of power is shifted in such families, because parents are used to relying on their children to translate and relay communications with the English-speaking world. Children whose parents do not speak the dominant language are forced to become good communicators. Of course, to be able to communicate symptoms, children must have enough self-awareness to know when their respiratory situation declines (Fritz et al., 1996). Children can be taught to have better accuracy in reporting symptoms to their parents. That much self-awareness and disease-awareness may come at a psychological cost, however. The disease can come to dominate a child's life.

Having asthma is both compatible and incompatible with the American ideal of what a child should be. Small says, "Every culture has its ideal, smart, well-functioning child. This ideal grows from historical, social, and political roots, and it is so ingrained in the culture that few question its validity. In America, that ideal is a highly verbal, independent, emotionally controlled, and self-reliant child. Social skills are seen as just that—skills to help one get along and be successful in an individualistic society," (Small, 1998:107). Asthmatic children are forced to learn to communicate their needs and be assertive with their parents. Yet they are less

independent, more needy, and less robust. Asthmatic children need constant vigilance and care from their parents. Not all mothers and fathers enter parenthood prepared to deal with a chronically sick child's needs.

As noted in the previous chapter, asthma is a very heterogeneous disease with many things that can exacerbate it. Consequently, parents often cannot be certain of which triggers are most important for their child. Parents can try to pick and choose between possible modifications to the home environment in a hit-or-miss fashion or can modify everything in hopes that some fraction of their effort will help their child. Parents have reason to be reticent about investing in environmental efforts to control asthma. In addition to the high cost in time and money, reluctance is compounded by uncertainty in the effectiveness of such efforts and lack of a way to measure the effectiveness. The condition and cleanliness of the living environment do have a powerful effect on the severity and long-term outcome of asthma. Hurtado argues that biomedical researchers and practitioners place too much emphasis on controlling symptoms through medication and too little on teaching people how to take control of their own health through modifying and maintaining their environment (Hurtado, 1999). Eliminating irritants and allergens in the environment is important for managing asthma. Many recommended environmental changes, though, can be very expensive and time consuming. Some are nearly impossible for indigent families dependent on public housing.

Housecleaning does reduce asthma symptoms (Kato et al., 1991; Mazon et al., 1994). Many poor people, though, live in housing so old, dusty, moldy, and

cockroach-ridden that it is virtually impossible to clean up enough to improve symptoms (Call et al., 1992). Parents may perceive the marginal benefit of investing scarce time and monetary resources to reduce household allergens to be low. Parents may also be aware that allergens exacerbate the condition, and that reducing allergens may improve their child's outcome, but may nevertheless lack the resources to make major household changes (Denson-Lino et al., 1993). A way to begin addressing how parents make decisions on how much time, work, and money to put into keeping their home clean for an asthmatic child would be to look at behavior in the ecological context of a natural setting from the viewpoint of optimization and cost-benefit assessments, as in optimal foraging theory (Winterhalder, 1987). The ways parents make decisions in a natural setting need to be studied in terms of marginal costs and benefits.

Low-income and less educated parents are also less able to effectively manage asthma medications for their children. Management through medications requires frequent medical monitoring of dosage and drug combinations. Therefore, parents need to be able to take their asthmatic children to frequent physicians' appointments. Families that rely on public clinics may have long waits at each visit. Transportation can also be an issue. One study found inner-city children used their asthma medications only 44 percent as much as prescribed (Celano et al., 1998). In addition, 27 percent used poor technique with inhalers that would prevent them from getting their dose, and 21 percent missed follow-up appointments.

PARENTAL INVESTMENT THEORY

Karl Marx, in an 1875 cover letter to Wilhelm Bracke accompanying his *Critique of the Gotha Program*, laid out the ideal of communism as "From each according to his ability; to each according to his needs." Critics of communist theory argue such a moralistic goal is impractical because it runs counter to human nature. Marx's famous principal has never been successfully put into practice. The Soviet Constitution adopted in 1936 contained a socialist modification, "From each according to his ability, to each according to his work."

Most people would like to think that "to each according to his (or her) needs" drives modern parenting and that "from each" is not even part of the equation in allocating family resources to children. Theoretical discussions of human behavior require assumptions about the motivations that underlie behavior. Theorists interested in how parents allocate resources for their children generally use evolutionary biology or economic theory to predict human behavior. In other words, most writing assumes that parents make choices, consciously or unconsciously, to maximize some future outcome. Economically-oriented theorists see children as valuable in a family only when they can produce labor or capital or have the potential to produce and contribute in the future. Sociobiologists focusing on genetic fitness see children as fulfilling the goals of a family simply by their existence—with the assumption, of course, that they will someday have children of their own. Both camps reach the sad conclusion that "to each according to his needs" does not

describe family behavior any better than it works at a macroeconomic level. Rather, resources are allocated where the least input is likely to reap the greatest reward.

The concept of "investment" is goal-oriented: input with expected return or time devoted to achieve some future result. Parental investment strategies can be broken down into two main issues: how many children parents chose to have (choice being either active or sometimes passive) and how they chose to allocate resources among their children. Any reference to "investment" begs to be quantified, leading to the question of what currency is most appropriate for analysis of parental investment? Three disciplines have developed theory on parental investment. Economics and sociobiology have both dealt with parental investment. To economists, parents are investing their current time and material resources to maximize the future income of their children and future ability of their children to contribute to the financial and material security of the parents. Fitness, in the sense of genetic contribution to future generations, is assumed by sociobiologists to be the driving force behind parental behavior. More recently, anthropologists developed a biosocial approach to parental investment theory that mediates between the principles of economics and sociobiology to construct a context-sensitive synthesis. These anthropologists take both economic and sociobiological theory seriously but add the fine human balancing of context. This context that shapes human responses to basis drives is what we mean by culture.

Becker (1981) provides a prime sample of the economic approach to understanding family and parenting behavior. He uses the theoretical frameworks

developed by the field of economics and applies them to family formation behavior, including marriage, births, and division of labor in households. Markets, not just markets of material goods but also other types of markets such as marriage markets and labor markets, shape behavior. Becker describes the trade-off between quantity and quality in children as a continuum in the reduced level of family resources available to each child as family size increases.

Sociobiology combines biology and the social sciences to uncover the biological foundations for animal and human social behavior. Sociobiologists assume individuals within any species are evolutionarily programmed for their primary goal to be maximization of their reproductive fitness—the sheer number of genes preserved and passed to future generations. Several sociobiological hypotheses useful for explaining non-human animal behavior have also been successfully applied to humans.

Sociobiological logic may be illustrated through a few brief examples. First, recent research shows that humans as well as other species respond emotionally and sexually to certain smells. Women, who possess a keener sense of smell than men, seem to prefer odors exuded by the immunological systems of men who are genetically most different from themselves (Wedekind et al., 1995). Such behavior could have species survival benefits by broadening the disease resistance of offspring. In another example, Geronimus (1987) seeks to explain higher pregnancy rates among poor and minority teenage girls and proposes that impoverished women maximize their reproductive success by having babies early, before their health

begins its relatively rapid decline and while familial resources from mothers and grandmothers are still available. Similarly, studies of potential carriers of Huntington's disease, a lethal autosomal dominant condition in which carriers are themselves affected but show no symptoms until early to mid adulthood, demonstrate that individuals with an affected parent—and therefore a fifty percent chance of being affected themselves—tend to have greater fitness than average for their population (Pridmore and Adams, 1991). Having more children increases the odds that carriers will have some descendants free of the disease; the problem, of course, is that it likewise increases the chance of passing Huntington's to another generation. Population geneticists propose that assuring at least a few offspring will be healthy takes precedence over stopping the spread of the defective allele. Single Huntington's mutations, for which survival is very sensitive to the reproductive practices of carriers, often survive for many generations.

Both the economic and sociobiological models of parental behavior are derived theoretically and neither necessarily relate to empirical observations of human behavior. The models work in some real-world contexts but not all. The difficulty of all social scientific attempts to predict human behavior is that social and biological phenomena are not closed systems governed by inviolate rules. Human behavior is messy. Models such as those proposed by Becker and the sociobiologists assume a rationality and single-purposefulness that is rare in actual human behavior.

Kaplan et al. (1998) give credence to both approaches, noting that the sociobiological model is grounded in biology and evolution, a foundation that

describes clear causal processes. Economic theories are based on a more artificial and abstract construct, that of utility. Yet economic models often fit real human behavior better. They contribute to a biosocial synthesis that uses sociobiological principles to address quality of life as well as genetic fitness.

Becker's economic algorithms take available resources within a family as fixed and beyond the control of family members. This assumption simplifies arguments but is not fully realistic. In reality, parents and other adults have some choice over several factors that influence family resources. Adults in a family can be more or less aggressive in their efforts to increase family resources. They can complete more education or work more hours. Extended family, such as grandparents, can choose to help with children or not. This point should not be interpreted as minimizing the constraints on families or placing blame on poor families, but does bring up another dimension in determining levels of parental investment.

In determining causes for differences in investment in children between families, three types of factors must be considered: (1) resources available to the family; (2) how much families tend to invest in children in general; and (3) the relative return-on-investment value of particular children. Becker distinguishes two types of resources families can invest in their children, human and non-human capital. The relative availability of these two types of resources is, to some extent, under control of families in inverse balance. That is, parents sacrifice human capital (their

personal time and attention to their children) to work for monetary, non-human capital.

"In the late-modern world the instrumental value of children has been largely replaced by their expressive value. Children have become relatively worthless economically to their parents, but priceless in terms of their psychological worth," (Scheper-Hughes and Sargent, 1998:12). A paradox in sociobiology is that as soon as the confounding economic advantages of children are gone, parents cease to reproduce to the maximum their health and affluence would allow.

Little theoretical attention has been directed toward distribution of resources between generations. What governs how a mother chooses to divide resources between herself and her children? Becker does address this question somewhat when he talks about the relative cost of children depending on the potential earning power of their mothers. He says, "[T]he cost of the mother's time is a major part of the total cost of producing and rearing children . . . Indeed, I believe that the growth in the earning power of women during the last hundred years in developed countries is a major cause of both the large increase in labor force participation of married women and the large decline in fertility," (Becker, 1981:98). A couple gives up an enormous amount of potential non-human capital when a well-trained and educated mother decides to invest her time in child rearing instead of earning a wage. Yet producing a child with the capacity for earning high levels of non-human capital (a child with the skills to get a good-paying job), requires a heavy investment in human capital on the part of parents. Thus the economic approach explains the negative relation between

income and fertility, an area where sociobiology fails. The effective price of children increases with income (Becker, 1981:102).

Empirical studies of real human societies show parenting behaviors are not as rigidly programmed as either sociobiological or economic models presume. "All mothers and fathers are evolutionarily designed to attend to infant signals, but they respond in all sorts of ways, ways that are culturally and personally molded," (Small, 1998:107). Behavioral plasticity does not guarantee optimum adaptation. Chisholm says, "This indeterminacy, or developmental plasticity, tends to increase individual inclusive fitness because it provides for more efficient environmental tracking. . . . On the other hand, if this information is sometimes actually detrimental to inclusive fitness, this may be the price we have to pay for the greater adaptability that this same plasticity gives us. No adaptation is ever prefect, and all adaptations represent a compromise between two or more selective pressures," (Chisholm, 1983:248-249). Behavioral plasticity, according to Chisholm, is what makes culture possible. The human ability to respond to a variety of situations in a variety of ways is adaptive but comes with a cost. In the main, the strategy of enormous behavioral plasticity has been a successful one for our species. Instances arise, though, where behavior is not optimum to affect the best outcome.

Differential parental investment is an important social issue that impacts child welfare. As important as the political economy is in determining demographic patterns of health and disease, Dettwyler (Dettwyler, 1994) has shown that individual circumstances often influence the growth and health of children more than does the

political economy or the wealth of family. In her fieldwork in Mali, she found that the distribution of resources within a family often determined child welfare more than total resources available to the family. The commitment and skill of parents have enormous influence on child health. Parental attention to children spans from smothering enmeshment to extreme neglect.

Kaplan, Dettwyler, Chisholm, Scheper-Hughes, and Hrdy all contribute to pulling together behavioral theory and placing it within a broader context. Scheper-Hughes leans toward the economic, materialist approach but also draws upon sociobiological concepts. Hrdy starts with sociobiological theory and incorporates economic principles. Hrdy describes the range of maternal attention in terms of cost and investment, even though her basic orientation is sociobiological:

> "Dual-career mothers, whether they forage or go to work, have always sought ways to mitigate the costs of infant care. Today, mothers hire nannies, leave children in government-run crèches, *maternales*, or daycare centers; they delegate childcare to kin; or else they continue caring for infants themselves but reduce the amount of care given to each infant. Reductions range from leaving an infant in a car-seat for fifteen minute while running an errand, to neglect so pronounced it results in an infant's failure to thrive. In the more extreme cases, consequences of these tactics are measurable. More often they are not. Even when maternal retrenchment affects morbidity or infant mortality, the effects of maternal decisions do not leave a measurable trace." (Hrdy, 1999:370)

Scheper-Hughes has shown that maternal bonding is not a biological universal and differs in different circumstances. Her main thesis is that no set formula can predict how mothers will behave in all environments, that maternal behavior is governed by ecological, cultural, and economic context:

> "[P]erhaps there is a middle ground between the two rather extreme approaches to mother love—the sentimental maternal "poetics" and the mindlessly automatic "maternal bonding" theorists, on the other. Between these is the reality of maternal thinking and practice grounded in specific historical and cultural realities and bounded by different economic and demographic constraints. Maternal practices always begin as a response to "the historical reality of a biological child in a particular social world (Ruddick, 1980:348)." (Scheper-Hughes, 1992:356)

Hrdy's stance is similar but with more of a biological spin:

> "A mother's commitment to her infant—and in the case of humans, this is what we mean by "mother love"—is neither a myth nor a cultural construct. As with other mammals, a mother's emotional commitment to her infant can be highly contingent on ecologically and historically produced circumstances. No one knows how the underlying mechanisms work. But it is a reasonable guess that such mechanisms involve thresholds for responding to infant cues. These would be endocrinologically and neurologically set, possibly during pregnancy and prior to birth, rendering a mother more or less likely to become engaged by infantile cues as she makes decisions about how much of herself to invest in her infant." (Hrdy, 1999:316)

Scheper-Hughes, a materialist, and Hrdy, more a sociobiologist, both describe the same phenomenon in the words of their differing theoretical orientations. Mothers do not always behave in ways optimum for the welfare of their children. They balance their needs and competing obligations against the needs of their children. Often, maternal behavior is not optimum for either the mother or her children. Sometimes behavior does not conform to predictive norms.

When one child has more perceived potential

If the collective needs of all children in a family are greater than available resources, parents may choose (consciously or unconsciously) to more fully meet the

needs of some children at the expense of others. In some cases, focusing family resources in one child can maximize intergenerational mobility. Primogenitor, an institutionalized form of investing in one child over the others, served to maintain the status quo of family wealth rather than promote the social mobility or maximize the welfare of all.

Most theory on differential allocation of resources favoring some offspring over others has dealt with sex ratio and parental investment biased by sex. Fisher and Trivers and Willard are the major theorists in this area, and their approach is sociobiological. Natural selection, both Fisher (1930) and Trivers and Willard (1973) contend, has favored parental ability to adjust the sex ratio of offspring through differential investment. Fisher addresses deviations from a primary sex ratio of 1:1 in varied environmental conditions. He focuses on the idea that the relative reproductive success of each sex is a function of the primary sex ratio and reasons that sex ratios will find equilibrium where the cost/return ratio for males and females is equal. The currency of cost is calories—both in material resources and work. Parents will invest more in the sex with the highest return per calorie expended. An example is that parents in cultures where brideprice is exchanged might be expected to invest more in a daughter who will bring in wealth than in a son who will cost wealth. Fisher addresses return benefits strictly in the sociobiological terms of opportunity for genetic contribution to future generations.

Trivers and Willard expand on this idea that the primary sex ratio influences the relative potential of males and females for reproductive success. They expect

their hypothesis to apply to humans equally as well as it does to other species. Development of the Trivers-Willard argument begins with the observation that the reproductive success of males is more variable. The majority of healthy women—at any fertility level—have at least a few births. An individual man, on the other hand, has the ability to produce many more offspring than one woman ever could. But, if very many men have high reproductive success, and the primary sex ratio is near parity, then some less successful men will necessarily be forced out of the game and unable to produce very many children or even any at all.

Based upon these suppositions, Trivers and Willard propose that males in good condition at the end of their parents' investment in them can be expected to produce more offspring than their sisters, whereas females will have greater reproductive success than their brothers if both are in poor condition. Males enjoy a fitness advantage only if their social environment provides them with enough resources to succeed in male to male competition. Trivers and Willard predict an especially strong effect in cultural settings where polygyny is practiced. Polygyny exaggerates both the greater potential and the greater variability of male reproductive success.

The preference for female offspring among poorer human populations predicted by the Trivers-Willard hypothesis has been demonstrated in a handful of cases. Sources of evidence used to establish the existence of biased investment include sex ratios, mortality rates, parents' stated preferences, and measurements of actual parental behavior. Potential examples that have been identified include the

Ifalukese of Micronesia, the Cheyenne of North America, the Herero of southern Africa, the Kanjar of south Asia, and the Mundugumor of New Guinea (Cronk, 1993). Gaulin and Robbins (1991) apply the Fisher and Trivers-Willard models of parental investment strategies to a sample of 900 mothers in the United States. Measures of maternal investment examined include birth weight, intervals between births, and commitment to breastfeeding. Some of their measures show patterns in the direction predicted by Trivers-Willard, and none are in the opposite direction. Across several cultural groups living in Australia and Malaysia, Callan and Kee (1981) establish a general trend of declining son preference from high- to low-fertility groups. Demographic data from the years between 1668 and 1879 in Ostfriesland, a northern German coastal region, demonstrate a pattern of parental preferential investment in daughters following the pattern predicted by Trivers and Willard (Volland, 1988). One-parent families in particular appear to have favored daughters.

The Trivers-Willard hypothesis is not without controversy, though, even as applied to non-human animals. For example, even though an earlier paper acknowledges the potential adaptive advantage of being able to adjust the sex ratio of offspring (Clutton-Brock and Albon, 1982), Clutton-Brock et al. (1985) conclude from data for red deer and other mammals that higher mortality rates among juvenile males result not from differential parental investment but from a greater susceptibility of males to food shortages, because more nutrition is required to support their growth rates.

Hrdy (1987), while exploring selective neglect and infanticide of offspring among primates and other mammals, notes that sex preferential infanticide among humans has been reported in nine percent of the world's cultures. Hrdy concludes, however, that the available evidence is too weak to fully address whether human sex biased infanticide follows the pattern predicted by Trivers-Willard.

This project concerns asthma, not sex biased investment. The question is how parental investment might be allocated to children differentially based on health or illness, robustness or weakness. Research testing the Trivers-Willard hypothesis, though, does show evidence of a tendency, as least under some circumstances, for parents to allocate resources among children based not on which are neediest but which will be able to affect the most successful outcome.

> "Under conditions of high mortality and high fertility, as still obtain on the Alto do Cruzeiro, a different, or a pre-demographic transition, reproductive strategy obtains: to give birth to many children and, on the expectation that only a few will survive infancy, to invest selectively in those considered the "best bets" for survival in terms of preferred sex, birth order, appearance, health, or perceived viability. Of course, to introduce the language of "investment" and "strategy" is already a deep cultural distortion. This is our cultural idiom, the language of the free market, in which infants are perceived as valuable biological and social commodities. I do not wish to suggest that reproductive thinking conforms everywhere to capitalist equations of "cost-benefit" analysis. Brazilian women do not keep a balance sheet on their offspring." (Scheper-Hughes, 1992:402)

In a controlled intervention study in a desperately poor community in Mexico, where malnutrition and undernutrition were rampant, some children were selectively given supplemental food while others were not (Chavez and Martinez, 1982). The supplementation began while their mothers were pregnant and continued while the

infants were breast fed and after weaning. The Chavez study dealt primarily with growth and physical development, but observations were also made on how extra food changed the way children interacted with adults and adults interacted with the children. The supplemented children received more attention. Their parents and neighbors doted on them. "It is customary in the community for the mother to provide everything for the child. The father does practically nothing. . . . In the case of supplemented children, there is greater participation in the care of the children by the rest of the family," (Chavez and Martinez, 1982:105). And also, "It was observed that some fathers of supplemented children carried the child in their arms and walked along the streets of the town so that neighbors and friends could look at it; in other words, the father was boasting about the child. What is more, some of these fathers frequently went beyond the levels of our study to participate in bathing the child and changing its diapers and clothing. It was never thought that this would happen in this town so it was not included among our classification on the questionnaire," (Chavez and Martinez, 1982:115). Fathers were proud of their more robust nutritionally supplemented children. People in the community even gave the supplemented children gifts of toys and clothing. Giving gifts to children was not a common custom in the community, but people responded more to the healthier, cuter, and more active children.

When one child has more need

This joy in healthy children—this is what is programmed into us genetically that drives us to want to have them, take care of them, have them around. This joy serves reproductive fitness. So what happens when the joyfulness of having a child is reduced? What about sick children? Does parental protectiveness always kick in to ensure they receive the extra care they need, even at the cost of other children or to the detriment of the parents themselves?

The previous section, on how parents respond to children with more potential, does not directly address the issue of this research project. This project, dealing with asthma, is concerned with children that have greater needs. Yet there has been much more research and theory on differential investment in children with more potential. Some work, such as that of Scheper-Hughes in a very impoverished community in Brazil, looks at how parents respond when some of their children have greater needs than others. Most work on this question, such as that by Scheper-Hughes, has been conducted in the context of large families in developing countries. A new approach is needed, looking comprehensively at how parents with smaller families in developed economies address the differential needs of their children. Systematic study needs to be made looking at just how far parents are willing to go to meet special needs of sick children and the context in which they make their decisions.

Taken in the broadest sense (and ignoring the issue of sex), Triver and Willard are saying that parents will invest most in the children likely to produce the most. Children likely to be most productive are often the least needy. So parents may

actually invest more in children who need less and invest less in children who need more. Is there empirical evidence of human parents actually practicing what would seem to be such a grotesque inequity? Yes, in fact there is. Most studies of parental investment look at the most clear-cut measure of investment versus non-investment: the decision to rear some children but not others. In other words, most are studies of infanticide. Infanticide can be either active or passive. A mother may actively cause her infant's death by smothering or abandoning it at birth. Some ethnographies record cases of infant death being brought about more gradually and passively by extreme neglect.

> "Even children with the same parents are born with different defects and abilities, and have different accidents, luck, and other experiences as they interact with their environment; stated formally, they have different values of market luck and endowed luck. Do neutral parents exacerbate the differences among their children by investing more in better endowed and luckier children, or do they compensate their less fortunate children? If parents invest in both the nonhuman and human capital of children, the marginal rate of return is the same for all children and equals the market rate on nonhuman capital . . . Rates of return are likely to be higher for abler children because they benefit more from additional human capital . . . differences in earnings would exceed differences in endowments because investments in human capital reinforce the differences in endowments." (Becker, 1981:123)

Poorer families, which Becker notes have only human capital to invest in their children, would derive even greater rates of return from favoring the better endowed children.

Scheper-Hughes records several instances of mothers refusing to provide special treatment or meet special needs of less healthy children, even when that means a child will die. Below are two examples from her book:

> "Zulaide, pregnant for the fifth time at the age of thirty-two, speaks of her puny one-year-old son sitting in her lap, 'He's still living, but he won't be for long! He can't stand up; he can't speak a word. He spends most of his day on the floor because I can't hold him in my arms all day. He has fevers and diarrheas, diarrheas and fevers. The doctors say that he will be like this unless I take him to the Children's Hospital in Recife. *But I can't afford to treat him special.* I couldn't breast-feed him because I am not in good health. It wouldn't help him or me, would it? I can't make him special foods. *He's no better than the others!* So he gets the same inferior quality milk in bulk that they do. I know it is too weak for him, and that's why he is so witless. But if he dies, so be it. He is not the only one I have.'" [Emphasis added.](Scheper-Hughes, 1992:370)

> "The last time I saw Terezinha in 1982, she spoke continually of the little boy's "hopelessness," his refusal to swallow more than a few tablespoons of *mingau* each day, his need for "expensive" treatments that could be gotten only at the expense of her other children." (Scheper-Hughes, 1992:388)

Scheper-Hughes provides clear examples of mothers choosing between their children on the basis of which would be most costly and which would be most likely to thrive, thus giving the mothers a good "return on their investment" so to speak. Hrdy addresses biased parental investment in terms of maximizing genetic fitness balanced against economic costs and utilities. She says, "[I]n the pragmatic and not-at-all-nice domain of Mother Nature, mothers evolved to factor in costs (which, in the human case, can range from mother's age or physical condition to a conscious awareness of future costs) as well as to factor in benefits (for example, a social milieu that offers sons better opportunities than daughters)," (Hrdy, 1999:363-364).

Hamilton devised a rule predicting that altruistic behavior, as an evolved trait, could be expected whenever fitness benefits are greater than costs to a giver (Hamilton, 1963; Hamilton, 1964). The point of this rule is to expand the concept of

reproductive success to include fitness of close relatives sharing genes by common descent. So a woman may be willing to help care for her nieces and nephews so long as helping them does not detract from caring for her own children. Hamilton's rule has also been used to argue that step-parents are less likely than biological parents to invest heavily in children. The logic would apply, though, to differential treatment by mothers of their own children. If some children are more likely to succeed—especially in terms of reproduction, while other children cost more and are less likely to succeed, then mothers may spend their time and material resources where their return on investment will be greatest.

Parental investment tends to be discussed in terms of quantity versus quality or distribution of resources between siblings. In other words, thought revolves around how parents choose between investing more in one child and investing instead in another child, whether the second child exists in fact or only in potential. Similar theoretical arguments can be used to address differences in investment within families can be applied to investment between families. The study presented in this dissertation includes full information on only one child per family and so cannot address inequality in investment among siblings. From a theoretical standpoint, though, the possibility of differential investment in some children more than others needs to be remembered.

If Becker is correct, then children are less costly for women with less education or marketable training. Some mothers may count on their children not being too difficult, expensive, or time consuming. A sick child may bring costs not

anticipated by its mother and may need more than she is prepared to cope with or can afford.

FAMILY FUNCTIONING AND ASTHMA

Family functioning plays an interactive role in all three levels of asthma development (host vulnerability, primary inducers, and secondary exacerbators). Numerous studies demonstrate a relationship between asthma and negative emotion (for a reviews see Wright, Rodriguez, and Cohen, 1998 or). Most have examined emotion using a personal, psychological approach. The larger family environment, however, may be more illuminating, particularly when addressing disease in young children. Schobinger et al. (1992) found that the fathers of asthmatic children were more likely to exhibit a critical attitude toward their asthmatic children than were fathers of non-asthmatic children. A study of mothers found similarly stressed relationships with their asthmatic children (Carson and Schauer, 1992). Studies have shown perennial asthma to be associated with psychological difficulties, increased mental illness, and behavioral problems whereas seasonal allergic symptoms occur more often in generally psychologically healthy children (Weder et al., 1993). Mental health tends to be worse among mothers of asthmatic children as well as among the children themselves (Frankel and Wamboldt, 1998). A study comparing reports from children and parents found that parents reported more internalized psychological symptoms in their children with severe asthma than the children reported in themselves (Wamboldt et al., 1998). Perhaps parents are more aware of

symptoms in their children or perhaps their responses reflected their own stress from having an ill child.

The failing of cross-sectional studies of family functioning and asthma is that they do not reveal the directionality of the association. Does a stressful family climate lead to asthma, or do parents tend to react more negatively to asthmatic children? It probably works both ways. A longitudinal study of psychological risk found that parents of asthmatic children already had more marital adjustment problems than control parents several years before their children began to have asthmatic symptoms (Askildsen, Watten, and Faleide, 1993). Mrazek and Klinnert (1991) used a longitudinal study to find evidence that parenting quality during infancy is associated with asthma onset in young children. According to their model, quality parenting can buffer infants from noxious stimuli; conversely, ineffective parenting, when combined with other family-related stressors, is associated with increased risk to the infant. They hypothesize ways in which stress can activate or alter a genetic predisposition but emphasize that the first issue that needs to be examined is how parenting style leads to increased exposure to a variety of risk factors in the physical environmental.

Risk factors in the physical environment that need to be examined in relation to family functioning include exposure to viral infections, use of medical care, and irritant and allergen exposure. How families compensate or fail to compensate for depressed circumstances needs to be examined. For example, smoking among socially disadvantaged mothers has been linked to coping with feelings of isolation

and low levels of physical and emotional energy (Graham, 1987). Research on the effects of family stress on influenza has found that family styles dysfunctional in either cohesion or adaptability lead to significantly more infection as measured by presence of antibodies (Clover, Abell, and Becker, 1989). Members of disengaged families demonstrate fewer cases of influenza infection, however, apparently because they are in less physical contact with other family members than are members of enmeshed families. Consequently, as viral infections are significant triggers for asthma onset, children from families that are less physically close may in fact be at slightly lower risk. Another consideration is that children from chaotically functioning families may be less likely to be taken to physicians for treatment of medical problems, including asthma. An unknown percentage of familial asthma may actually relate to inter-generational family functioning and living styles rather than genetics alone.

IN SUMMARY

Well-documented physiological mechanisms increase risk of allergy and asthma in people emotionally or psychosocially stressed. The converse is also true, that emotional and social support can improve symptoms and outcome in asthmatic people.

For parents of asthmatic children, managing their child's illness is a costly and time-consuming challenge. Parents with more than one child may have to make hard choices in how much additional effort to put into managing the symptoms of their

sick child. Clearly, many parents work hard to optimize the health of children with asthma. There are competing forces, both biologically driven and economic, that may make it impractical for some parents to implement every measure a physician could recommend. It is imperative that more research be done to determine the most cost effective and time efficient steps that low-income parents can take to alleviate asthma symptoms. Few families of any income can take every step that has been suggested for reducing allergens in the home. Evidence-based prioritizing is essential so that busy parents with completing responsibilities can know what steps will be most worth their time with the goal of maximizing the health of their children.

The two chapters of literature review have dealt with both biomedical and biosocial/sociocultural research and theory. The many factors that can predispose to asthma by reducing lung function or, especially, by tipping immunity toward Th2 activity, are biosocial. The immune capacity to produce IgE is a trait evolved to boost survival and fitness in an ecological context where humans and parasites co-exist. The existence of IgE is closely related to human subsistence strategies from the past. The fact that IgE now offers few benefits and mainly causes problems for humans is also a subsistence issue. Industrialized people live in urban areas removed from livestock and drink purified water, so they have little contact with parasites. Demographic characteristics of people prone to asthma also relate to behavior or evolution. The deprivation, social stress, and allergen-ridden living conditions of people on the lower socioeconomic rungs, for example, leave them more vulnerable to allergic disease. Marriage and childbearing patterns determine household size.

Number of people living in the household has been shown to influence a child's risk of asthma. Whether a mother smokes is likewise a sociobehavioral issue involving societal norms, addictive behavior, and coping strategies. Behaviors and social issues underlie variation in fetal growth and also in obesity. Diet and exercise, in particular, surely have a large impact on asthma rates.

In short, virtually all the major factors thought to determine population patterns of asthma prevalence are essentially cultural and behavioral issues. Understanding of the physiological processes will come from the biomedical sciences. Truly understanding why some groups have more asthma than others, why asthma rates are increasing, and how the trend can be arrested will require the tools of the social sciences. Anthropology, by embracing both human biology and human behavior and how the two interact, is positioned to be able to contribute in many ways to understanding the trend of rising asthma rates among children living in modern, urban societies.

CHAPTER 4
Methodology

PROJECT SUMMARY

This is a prospective cohort study of mothers and children who took part in a 1988-91 prospective study of fetal growth. Data from the original pregnancy study are incorporated in the design. Twelve hundred and eight (1208) women and their neonates completed all key parts of the original study protocol. From these, 131 mothers and children were followed up in home studies the summers of 1995 and 1996, when the children were four to seven years old. This subgroup forms the basis for analyses reported here.

The project examines factors associated with (1) development of asthma in young children, (2) management of ongoing asthma within the family, and (3) ways the illness changes the lives of children and relationships within the families. In-depth analyses dissect ways anthropometric factors influence host vulnerability by testing hypotheses relating to (1) birth weight, distinguishing between intrauterine growth rate and gestational age, (2) childhood growth, and (3) maternal obesity. Sibling size, maternal parity and age, and daycare attendance are investigated. Social stressors within families that contribute to asthma in children are explored. Social elements that affect the ability of mothers to maintain cleanliness in the living environment are explored. Finally, this inquiry probes the ways asthma changes the lives of children, by changing relationships with their parents, the amount of time

they play outdoors, how their mothers' perceive their personalities, and their language development. The influence of a child's asthma on family functioning (measured by family cohesion and adaptability) is considered.

RATIONALE BEHIND THE STUDY DESIGN

A prospective cohort approach

In biosocial research, congenital and environmental/behavioral processes may be nearly inextricable. One way to approach the task of disentangling the determining elements of a disease process is through longitudinal studies with careful attention to serendipitous variation and the onset of multiple variables. Most research in childhood asthma has been on clinical patients or based on population databases. Most home studies have been limited in scope, focusing on narrow interests such as microbe analysis of household dust. More extensive home-based studies usually concentrate on children identified with high hereditary risk. With asthma prevalence increasing rapidly, more needs to be known about factors that increase risk for people, regardless of their family history of asthma.

Integrating quantitative and qualitative data

Since the validity of research data depends on each observation being made in the same manner, closed questions with standardized multiple answers are often the most appropriate. But the additional information respondents impart outside the standardized questionnaire sometimes provides the most useful leads. Semi-

structured, open-ended charts were used to plot major social and health related events in the mothers' lives. Investigators encouraged the mothers to discuss issues brought up by the questionnaires or mentioned in passing. The questionnaire forms had space for comments and interviewers wrote up fieldnotes after every interview.

The study sample

To address the greater socio-ecological context influencing whether a child develops asthma and in which health management decisions are made, the units of analysis are the mother-child dyad and household rather than individual children. Independent variables are placed in the broader context of maternal education and life history, family resources, attitudes, and physical characteristics of the home and neighborhood.

The focus on four-to-seven-year-olds has several advantages. Children that age have the highest prevalence of asthma and the steepest increase in prevalence (CDC, 1998b). The etiological model requiring susceptibility and exposure before onset of asthma symptoms implies that in the case of childhood asthma, precipitating conditions must be present very early in life. As the prenatal and neonatal periods are times of susceptibility in themselves, they are of particular interest in this study. A general prediction is made that histories of childhood asthma associate with factors very early in life, without regard to degrees of morbidity.

Environmental influences are easiest to study in young children that have not begun to spend much time away from home. Few of the children in this study sample

had started regular school, though some attended daycare. Four-to-seven-year-olds are in the narrow stage of life lifecycle specialists define as *childhood*, out of infancy but before the greater autonomy and self-sufficiency of juveniles. Personality characteristics are becoming recognizable, at least as perceived by parents. Though outside cultural influences are undoubtedly extensive, experiences of the children are still filtered through the mediating influence of primary caregivers. For that reason, the attitudes and behaviors of their parents have more effect on their physical surroundings and enculturation than at any other stage. A young child's environment is primarily the home and family, especially the mother.

Another advantage of using subjects four to seven years old in epidemiological research is that sex differences are minimal in that age. Differences in the health and growth of boys and girls are least in early childhood. In the United States, children beyond infancy have the lowest mortality of any age group (U.S.D.H.H.S., 1993). Young children also have the least difference in male-to-female mortality rates of any stage of life (UN, 1992) and the smallest secular increase in sex mortality ratio (Held, 1995; Wingard, 1984). Enigmatically, although these childhood years have the lowest excess of male over female mortality, they are also the only stage of life in which males have more reported total morbidity [Nathanson, 1977 #1265; Gissler, 1999 #577]. As discussed in the chapter on Asthma Literature Review, morbidity from asthma is slightly higher in little boys. In every other stage of life, females report more total illnesses—not just asthma—despite lower mortality (Gove and Hughes, 1979; Nathanson, 1977; Verbrugge, 1976;

1985; 1989; Verbrugge and Wingard, 1987; Waldron, 1983; Wingard, 1984). Therefore, the pattern of morbidity rates relative to mortality rates is reversed in young children from all other age groups.

The childhood years, from infancy until about ten years, are the only years that in the absence of marked stress or deprivation, growth velocities of boys and girls are nearly the same (Bogin, 1988:45-46). Sexual dimorphism in body size, which originates prenatally, is lowest in childhood. Given no adverse environmental influences, a similar level of sexual dimorphism as was present at birth can be expected in these young children, before the first height crossover when girls begin their more rapid growth. Those years are, therefore, advantageous for distinguishing prenatal and environmental influences on the growth of children while minimizing the confounding element of the child's sex.

TIME REFERENCES

In a longitudinal inquiry of this sort, clarity in tracking sequence is essential for inferring causes and effects. Throughout this document, Time 1 (T1) refers to data collected prenatally, Time 2 (T2) refers to a child's birth and neonatal assessments immediately after, and Time 3 (T3) identifies the 1995-96 follow-up home interview, when the children were between four and seven.

STUDY DESIGN

Time 1 and Time 2 – The OUHSC Pregnancy Study

The original study of pregnancy outcome and infant birth weight, formally titled "Effects of Family Structure and Function on IUGR and Prematurity" but herafter referred to as the OUHSC Pregnancy Study, was conducted by the University of Oklahoma Health Sciences Center (OUHSC) with Troy Abell, PhD, MPH as the principal investigator. The study was funded by the National Institute of Child Health and Human Development (NICHD R01 HD20511). The UOHSC Institutional Review Board approved the involvement of human subjects.

Participants were recruited at their first prenatal visit to the University Hospital or either of two family medicine clinics in Oklahoma City, from the fall of 1988 to the fall of 1991. Verbal competency in English was required. The criteria for exclusion were multiple gestation, known fetal congenital anomalies, being under the care of a correctional or mental institution, or receiving psychotropic drugs for the treatment of mental illness. The women, or their parent or guardian if less than 18 years of age, gave written consent to participate.

The public clinics where the participants were enrolled serve primarily Medicaid patients, including both indigent women and women from low to middle-income working families without insurance. A few women with private insurance are drawn by the staff's training and experience to seek prenatal care at Oklahoma Medical Center clinics and deliver at the University Hospital. Because the study enrolled women that came for prenatal care any time up to delivery and because

nearly all women in Oklahoma receive some prenatal care, the sample includes many under-served women and children that might not be reached through other agencies.

Time 3 – The OU MCH Study

Detailed home studies were conducted with a subsample of 131 preschool to beginning school age children from the cohort whose mothers participated in OUHSC Pregnancy Study during their pregnancies. The OUHSC Institutional Review Board granted approval again for the follow-up. Graduate and honors senior students enrolled in an ethnographic field school in the Anthropology Department at the University of Oklahoma gathered data over the summers of 1995 and 1996. Current hospital billing records were used in an effort to contact all of the 1208 mothers that completed the OUHSC Pregnancy Study. The refusal rate of women contacted again was low. Informed consent was obtained from the mothers for their and their children's participation in the study and for the investigator to access their children's medical records.

Pairs of interviewers conducted home visits with the mothers and index children. The interviewers were not aware of previously collected data. One interviewer talked with the mother while the other talked with the child and evaluated the home environment. The interviewers worked together in taking lung function and anthropometric measurements of the mothers and their index children. Families were cooperative in giving interviewers access to their homes and yards. Most women expressed pleasure with being a part of a large, ongoing project and appreciated the

attention to their wellbeing. Accordingly, they were generally open and thoughtful with their answers to interviewers. Many volunteered information about their lives, problems, attitudes and beliefs, activities, and how they managed.

DATA COLLECTED

Time 1 – Prenatal data

Data collection in 1989-91 included: (1) an interview and anthropometric assessment at the initial medical prenatal visit and again at about 32 weeks gestation; (2) an assessment of the neonate 12 to 24 hours of birth; (3) a postpartum anthropometric assessment of the mother; and (4) a chart abstraction of each medical prenatal visit, the delivery, and postnatal period.

Prenatal questionnaires

The women completed two series of questions at their initial prenatal visit and the follow-up interview near 32 weeks gestation. The first set of questionnaires contained 133 questions, the second 244 questions. Together, the questionnaires covered socio-demographic data, medical history, family attitudes toward the pregnancy, sources of social support, health behaviors and lifestyle factors, and plans for childcare. Information included data on income, ethnicity, education (number of years of school the mother completed), current job, father's current job, total household income, type of home (whether the mother's home was bought or rented), how many living in the home, marital history and status, and previous pregnancies and births.

As a measure of socioeconomic status (SES), the study used Nam's occupational status index developed for the U.S. census. For each occupational title, the Nam index takes the average percentile of educational attainment and income (the percentile for education of that job title plus the percentile for income of the job title divided by 2). Thus, the index ranges from 0 for the lowest status job (given average educational and income levels for that job title) to 99 for the highest status job.

Participants were asked to specify who lived in the household, and their answers were summarized as four separate variables: (1) number of people, (2) number of generations, (3) type of family, and (4) whether the household was the participant's family of origin. Types of family structures were grouped into (1) single parents alone with children, (2) nuclear families (husband or birth father and wife with or without children), (3) extended families *with* husband (husband or birth father and wife plus other kin besides children), (4) extended families *without* husband (wife and other kin besides children), and (5) other.

The women answered extensive questions on their health history and habits. Medical conditions noted relevant to asthma include history of pulmonary disease (including acute), history of chronic pulmonary disease (type specified, including asthma), and asthma medications (whether the mother was being treated with any type of asthma medication during the pregnancy and what type). For their smoking histories, they were asked whether they (1) ever smoked, (2) stopped smoking before conceiving, (3) stopped smoking in the first trimester, (4) stopped smoking in the second trimester, or were (5) still smoking. If they were still smoking, they were

asked how many cigarettes per day. They were also asked about other smokers in the house, who smoked most, and about how many cigarettes a day that person smoked. Women were asked about their history of recreational drug use, the types of drugs they had ever used, and whether they were still using them. They were also asked about alcohol use. Detailed questions were asked about exercise habits.

Additional information gathered from the woman included details of their relationship with the fetus's biological father, sources of emotional and financial support, their feelings about the pregnancy when they learned of it and at the time of the interview, and their family's attitude toward the pregnancy. Questions also addressed the women's occupation, plans for working outside the home after the baby's birth, childcare plans, and whether they were on government assistance or planned to go on government assistance after delivery.

FACES II

The women completed the Family Adaptability and Cohesion Evaluation Scales (FACES II). As a theoretical framework for addressing an interactional concept of stress and social support, the series of Likert scale questions is based on the Circumplex Model of Marital and Family Functioning (Olson et al., 1982), which posits that cohesion and adaptability are the best major dimensions describing functional and dysfunctional family systems. Cohesion is defined as "the emotional bonding that family members have towards each other." Family adaptability is defined as "the ability of a marital or family system to change its power structure, role relationships, and relationship rules in response to situational and developmental

stress" (Olson, Sprenkle, and Russell, 1979). These two dimensions are hypothesized as related curvilinearly to healthy outcomes. That is, that (theoretically) the extremes of cohesion, enmeshment, and disengagement are unhealthy, while the mid-range is thought to be healthy. The same is thought to be true for adaptability, with extreme ends of the scale being labeled rigid and chaotic. Alpha reliability for FACES II is .87 for cohesion and .78 for adaptability. Factor analysis supports the validity of the construct, and a national survey provided data for discriminant and predictive validity. The enmeshment and disengagement scores are derived by isolating items on both extremes of a 17-item subscale of cohesion.

Maternal anthropometric measurements

Maternal triceps and subscapular skinfolds, forearm and thigh girths, height, and weight were measured at the initial and 32 week prenatal visits, beginning at the first one.

Maternal medical records

Medical records from the prenatal visits and delivery were abstracted. Data of interest in the current study include weight gain, the woman's history of diabetes, hypertension, acute and chronic pulmonary disease (type specified, including asthma), and use of medications to treat chronic conditions.

Time 2 – Birth and postpartum data

Infant anthropometric measurements

Infants were measured 12 to 24 hours after their birth. A trained nurse or research assistant carried out a complete Dubowitz assessment of gestational age (Dubowitz and Dubowitz, 1977) and measured the circumferences of the head, chest, arm, and thigh. Crown-heel and crown-rump lengths were measured with a neonatometer, and mid-arm, mid-thigh, and interscapular skinfold thicknesses were assessed with Lange™ calipers. Birth weight was recorded from the delivery record.

Delivery and neonatal medical records

Delivery records were abstracted for one and five-minute Apgar scores, type of delivery, number of minutes of labor, presence or absence of fetal distress, presence of absence of respiratory distress (including whether oxygen or ventilation was required), presence and extent of meconium staining, placental weight and any abnormalities, presence and type of infection in the infant, Rh and ABO incompatibility if noted, urine drug screen results, birth and discharge anthropometric measurements, physician-estimated gestational age; and length of neonatal hospitalization.

Time 3 – Follow-up data on children 4 to 7 years old

Research teams in the 1995-96 follow-up used various methods of gathering data including: 1) questionnaires administered to mothers; 2) ethnographic life histories provided by the mothers; 3) questions asked of the index children; 4)

ethnographic details provided by the children and obtained from observing family interaction and characteristics of the home environment; 5) anthropometric measurements of both the mothers and index children; 6) lung function tests on both the mothers and index children; and 7) a survey of interior housing characteristics and cleanliness. Another research assistant drove by each home and through the neighborhood to survey characteristics of the home exterior and the neighborhood.

Questionnaires completed by the mothers

Mothers completed questionnaires including 1) a life chart, 2) additional questions on life events, 3) FACES II, 4) a child's health questionnaire; and 5) a history of alcohol use in the family. A questionnaire on ethnicity was added the second summer. Questions were read to the mothers in most cases to ensure completeness, facilitate reliability, and control for variations in reading ability. Women that preferred could fill out the questionnaires themselves, but the interviewers went over their responses with them.

Life chart

Semi-structured, open-ended life charts were used as an interview tool in eliciting details of events and health-related choices the mothers had made but would be difficult to collect in questionnaire format. Interviewers probed extensive life histories, charting changes and events in the life of each woman for every year since they were fifteen. Charts began with pregnancy histories, with space for recording the name, sex, birth date, and birth weight of each child, then all other pregnancies and their outcomes, and infant feeding choices. The woman's own health history was

next, showing her major illnesses, weight gains, and smoking history. Education and work history, household composition, address changes, male partners, jobs, jobs of partners, income sources, and government assistance were charted.

The graphic, temporal arrangement of information encouraged women to expand on their own life narrative, to interpret events and make their own causal connections. The life chart was a catalyst for some women, prompting them to recall details of their life. For example, they would stop and think where they were working in a particular year and then relate details about what was going on at that time. The temporal context of information helped them connect events better than a simple questionnaire. The charts also aided interviewers in recognizing areas where further probing might flesh out a better notion of the forces that shaped the woman's life and uncover connections the informant might not have explained.

Additional questions

A traditional questionnaire elicited information to supplement the life chart. Questions addressed two specific times in the woman's life, her childhood and family of origin and her circumstances when her first child was born. Other information collected included her age at menarche and first intercourse, the relationships of each of the biological fathers to each of her children, education level and occupations of her sisters, and her everyday access to an automobile.

FACES II

The mothers were asked to complete the Family Adaptability and Cohesion Evaluation Scales (FACES II) again (Olson et al., 1982). The instrument was

administered this second time so that recent scores could be compared with prenatal scores. Between the first study and the follow-up, most families would have undergone changes in composition and functioning style. The index child had at least joined the family, very likely changing family relations.

Child's health questionnaire

Mothers completed a detailed questionnaire on the health history and status of their child, the child's school and daycare history, safety practices and rules for the child, use of heating, air conditioning, and the stove, the mother's smoking history, and how often the child was exposed to passive smoke. The questionnaire probed in detail respiratory conditions relating to asthma and wheezing. Mothers that identified their child as asthmatic answered additional questions about the child's symptoms, treatments, and modifications to the home environment they might have made to help control the child's symptoms.

Ethnicity

Mothers interviewed in the second summer only were asked about their ethnicity and the ethnicity of the index child. Questions were also asked about the ethnic makeup of the mother's closest friends, the child's closest friends, their neighborhood, and the child's school. The same questions were asked about the mother's own childhood. She was asked whether she thought people of her ethnicity were discriminated against and whether she herself had ever felt discriminated against in housing, school, jobs, or anywhere else because of her ethnicity. The form included questions about the mother and child's social activities and groups.

Questions asked of the children

Children were asked a short series of questions about chores around the house, friends spending the night, playing (with friends and alone), favorite toys, and how often an adult read to them. The purpose of the questions was to identify children from abnormally chaotic or enmeshed families, to identify the level of the child's gender role behavior, and to give researchers an idea of the child's ability to understand simple questions and make appropriate responses.

Family circle

Children were given a sheet of paper with a large blank circle on it. They were then shown several small construction-paper figures representing men, women, and children. The interviewer asked them to use the figures to make the child's family on the sheet. Then the interviewer marked where the child placed each family member and labeled each with the name preferred by the child. The family circle allowed children to create their own emic view of their family.

PPVT-R

The Peabody Picture Vocabulary Test-Revised (PPVT-R Dunn and Dunn, 1981), an instrument to assess a child's receptive (hearing) lexicon of standard English, was administered to each child in the home setting. The test involved showing the child a series of sets of four clear, bold-line drawings. For each of the pictures, the interviewer said a word and asked the child to point to the picture illustrating that word. No reading, writing, or oral response was required. The

PPVT-R provides a raw numerical score, an age equivalent score, and a nationally standardized percentile rank.

Anthropometric measurements

Anthropometric measurements of the mothers and children were taken with six- foot steel rulers, fiberglass tape measurers, portable Sunbeam™ scales, and Lange™ skinfold calipers. Measurements were taken of height, weight, long bone lengths, forearm, biceps, wrist, thigh, head, chest, waist, and hip circumferences, and biceps, triceps, subscapular, forearm, and thigh skinfolds. Limbs were measured on the left side.

Lung function

Lung functions of both the mothers and children were taken three times, the final assessment being the best of three attempts. Lung function was collected using Respiradyne™ Pulmonary Function Monitors, small, rechargeable, hand-held instruments that show the following key forced exhalation parameters: forced vital capacity (FVC), forced expiratory volume in one second (FEV_1), FEV_1/FVC ratio, peak flow, forced expiratory flow 25%-75% ($FEF_{25-75\%}$), and extrapolated volume ($VOL_{EXTRA}\%$). Analyses used the highest of the three recorded FVC, FEV, and peak flow measurements. The FEV_1/FVC ratio, $FEF_{25-75\%}$, and $VOL_{EXTRA}\%$ measurements were used from the attempt with highest sum of FVC plus FEV_1. Parameters are defined as follows (Wanger, 1996:x-xi, 41-42):

FVC—forced vital capacity, the total volume of air that can be expired with maximal force after inhaling as must as possible.

FEV_1—forced expiratory volume in one second, the volume of air exhaled in the first second of the FVC. A normal FEV_1 should be at least 80 percent.

FEV_1/FVC ratio—the ratio of forced expiratory volume to FVC as a percentage, calculated as FEV_1 divided by FVC times 100.

Peak flow—maximal rate of expiration, calculated as the volume of air per unit time.

$FEF_{25-75\%}$—mean forced expiratory flow in meters per second in the middle half of the FVC. $FEF_{25-75\%}$ is believed to be relatively independent effort giving clues to the status of the small airways. Low values can reflect early airway obstruction.

VOL_{EXTRA}%--extrapolated volume, the percentage of air exhaled before a person begins blowing as fast as possible. The VOL_{EXTRA}% should be low, ideally less than 5 percent.

Living environment

A quantitative check list was used in assessing housing conditions and the quality of interior air. Included in the list are such factors as the number of people living in the house, number of smokers, any fur-bearing pets, type of heating and air conditioning, type and condition of flooring, number of people sleeping in the room with the index child, and scales of neatness, cleanliness, and clutter in the child's room and the home in general. Square and cubic footages of interior living areas were collected by using a hand-held electronic measuring device. Indoor temperature

and humidity were taken with an electronic Hygro-term™ device. For control, exterior temperature and humidity were noted along with the time of day. Dust samples from a square meter of floor near where the child slept were taken with a hand-held Dustbuster™ vacuum covered with a square of well-washed sheet material for a collection filter. The dust samples have not been analyzed.

Fieldnotes

Interviews with the mother and child were written up separately. By writing field notes as soon as possible after each interview, interviewers could record details not covered fully in the questionnaires, make etic observations from the interviewer's viewpoint, and describe the social and physical context of the home and circumstances of the interview.

The interviewers that talked to the child also measured the house. By moving around the house, they had an opportunity to observe the living environment. Going through each room, they noted details that had a bearing on health and wellbeing and indicated lifestyle. What kind of toys and playthings or playplaces were available? Did the child have a place to draw? Were children's or adults' books visible? Interviewers noted the condition of bathrooms, kitchens, heaters and air conditioners, flooring, and sleeping arrangements. What was the home's state of repair? Were soap and toothbrushes available in the bathrooms? Was the house comfortable, or was it dark, cramped, or hot and stuffy? Did drinking, smoking, or drugs appear to be prominent in the lives of the family members? As the interview with the child was shorter than with the mother's, the person interviewing the child had time to talk and

play with the child and spend time with the child in the mother's presence to develop an impression of how they interacted. Anything that seemed significant or unusual was noted.

The interviewer that talked with the mother also wrote up fieldnotes to flesh out details not clear from the questionnaire. Notes from those interviews include descriptions of extraordinary periods in the life of the family, particular challenges faced by the woman or other family members and details the woman may have offered about her childhood and family of origin. Health and development information from the mother on the index child's siblings was recorded, along with clues to the mother's attitudes toward such issues as gender, race, religion, family, and child rearing. Observations of the mother's behavior were noted. How did she respond to being interviewed? Did she make efforts at hospitality, such as offering something to drink? Did she smoke during the interview? Interviewers often described their level of confidence in the information women gave and any observations that contradicted a woman's answers on the questionnaires.

Other incorporated data sources

Tax assessor data

County tax records on addresses at follow-up were collected, showing assessed values of houses and their age, size, and condition in 1996.

Children's medical records

Medical charts of indexed children at Children's Hospital of Oklahoma were abstracted from birth through the follow-up interview. Dates and diagnoses were recorded from each visit, both inpatient and outpatient. Other information included whether the child was diagnosed with asthma, number of lower respiratory tract infections, number of accidental injuries, and any instances of physical or sexual abuse.

PRIMARY DEPENDENT VARIABLE: ASTHMA IN THE CHILDREN

The primary outcome of interest, asthma prevalence among the index children, was assessed from different sources: (1) mother's report of physician diagnosed asthma, (2) physician diagnosed asthma or hyperreactive airway disease in the child's medical chart at Children's Hospital of Oklahoma, and (3) mother's observations of symptoms. Combining methods of identification helps balance out the biases inherent in any one method. Results from each source were cross-checked to uncover inconsistencies. A combined variable was created reflecting either the mother's report of asthma previously diagnosed by a physician or a physician's diagnosis from the medical chart.

TRAINING OF INTERVIEWERS

Interviewers were anthropology majors, either honors seniors or graduate students, taking part in the project through an ethnographic field school in the

Anthropology Department at the University of Oklahoma. The author participated in 75 of the 131 interviews, 57 percent. The students were trained extensively in each of the specific data gathering protocols and in interviewing techniques and general observation. They understood that the interviews and questionnaires primarily reveal the informants'emic viewpoints but that as interviewers, they needed to watch for clues for developing an etic view of the lives of the families they visited. These outsider assessments are reflected in variables gathered on housing condition and, most importantly, in fieldnotes.

Particular attention was given during training to accuracy and consistency, to reduce inter-observer bias in taking anthropometric measurements and measuring lung functions, in measuring rooms, gathering and packaging vacuum samples, and taking temperature and humidity readings. During training, interviewers saw slides illustrating how to evaluate cleanliness, neatness, and clutter in homes, to recognize different types of heaters and air conditioner and other characteristics of buildings, as well as how to evaluate neighborhoods and the outside appearance of houses.

STATISTICAL METHODS

Quantitative data were entered into SAS databases (SAS Institute Incorporated, 1989-1996). Univariate descriptive statistics summarize the characteristics of the families in the sample. Hypotheses are tested primarily through bivariate statistics, with multivariate methods used when appropriate to control for modifiers and assess relative importance of multiple variables. The hypotheses have

been divided into three sets. The first and second sets of hypotheses concern children that had asthma and those that did not, a binary outcome. Asthma is the dependent variable in the first set of hypotheses. It is the independent variable in the second set. Student's t tests are used in testing the difference between means on continuous independent variables by the binary dependent variable. Contingency table analyses with chi-squared tests of statistical significance are used for discrete independent variables. Hypotheses in the third set are addressed primarily ethnographically. Choices of ways to treat and analyze specific variables are explained in the analysis chapters as they arise in hypothesis testing.

Selecting a standard for the alpha levels to recognize as statistically significant involves balancing the risk of a Type I error (rejecting the null hypothesis when it is true) against the risk of a Type II error (failing to reject the null hypothesis when it is false). Frequentist scientific thought being conservative, minimizing risk Type I errors is given priority. In this study, alpha was set at 0.05. In a few cases, relationships with higher p-values are included in exploring ideas relevant to larger issues, even though the relationships do not reach formal statistical significance. An alpha of 0.10, for example, signifies a 10 percent chance, if the null hypothesis is true, that at the relationship in question results from random variation. But it also means there is a 90 percent chance, if the null hypothesis is true, that the relationship is not due to chance. So that readers can judge the strength of the evidence themselves, actual p-values are presented in all cases, along with the number of observations, and the magnitude of the effect.

When appropriate for theoretical reasons, statistical analyses are broken down by sex of the child or the two major ethnic groups in this sample, European-Americans and African-Americans. As population prevalence rates of asthma vary by sex and ethnicity, it is important to learn as much as possible about how risk factors may differ for each group.

HYPOTHESES

Set 1: Host characteristics and primary risk factors—predicting which children develop asthma

Figure 1 depicts the model that is the basis of Set 1 hypotheses. The dependent variable is physician-diagnosed asthma in the index child. The flow chart illustrates the factors posited to contribute to the initiation of the disease in children. Two parallel chains of events must come together for a person to be sensitized to atopic asthma. The top chain includes factors that come together to create a host susceptible to asthma. The bottom chain of factors lead to allergen exposure. Factors in all the darkened boxes are considered necessary for sensitization. But all these dark-boxed conditions have been prevalent in modern populations for several decades, and asthma rates continue to increase. Therefore, it is assumed these conditions are not sufficient in all people. The boxed question mark in the figure represents factors still unknown and almost certainly multiple that contribute to susceptibility in hosts. Factors that tip the immune balance toward Th2 reactions

might fill a large part of this box, but another factor would still be missing. The unknowns are missing elements that make the two chains of events sufficient for some children to have asthma that otherwise would not develop the condition. Note that the missing elements are posited to be in the chain leading to susceptibility. (The social and behavioral factors that lead to increased allergen exposure in the living environment still need to be explored more, but that is not part of this project.)

Hypotheses in Set 1, except for the first four, seek to partially fill in the question mark in the white box. Statistical analyses of quantitative variables are used to test these hypotheses. Some ethnographic observations are incorporated to help interpret the statistical findings. The Set 1 hypotheses are:

Hypothesis 1—Children of asthmatic relatives will have more asthma.

Hypothesis 2—Cleanliness and condition of homes will not explain the variation in asthma among children.

Hypothesis 3—Maternal smoking will not increase risk of asthma in children.

Hypothesis 4—Exposure to more people, as a surrogate for viral exposure, will not predict asthma in children.

- ***Hypothesis 4a***—Asthma prevalence among children will not associate with time spent in group daycare.
- ***Hypothesis 4b***—Asthma prevalence among children will not associate with number of people living in the household at birth or at follow-up.

Hypothesis 5—A mother's pregnancy history will predict asthma in children.

- ***Hypothesis 5a***—children born to mothers of higher parity will be less likely to have asthma
- ***Hypothesis 5b***—children born to mothers who have had elective abortions will be more likely to have asthma.

Hypothesis 6—Asthmatic children will have younger mothers.

Hypothesis 7—Asthma will be more prevalent in children of mothers with higher body mass.

Hypothesis 8—Asthma will be more prevalent among children with lower birth weight. Disaggregating birth weight categories will produce stronger patterns:

Hypothesis 8a—Prevalence of asthma will be higher in children born at earlier gestational ages, regardless of birth weight.

Hypothesis 8b—Retardation of prenatal growth will increase the risk of asthma later, and the consequences of asymmetrical growth retardation will be greater than symmetrical growth retardation.

Hypothesis 8c—Asthmatic children will have had smaller chest circumferences and shorter trunk-to-leg ratios at birth.

Hypothesis 9—Asthmatic children will not differ significantly from other children in their current weight-for-height-for-age.

Hypothesis 10—Asthma will be more common in children born into difficult social situations.

Hypothesis 10a—Asthma will be more common in children of single mothers.

Hypothesis 10b—Asthma will be more common in children of less educated mothers.

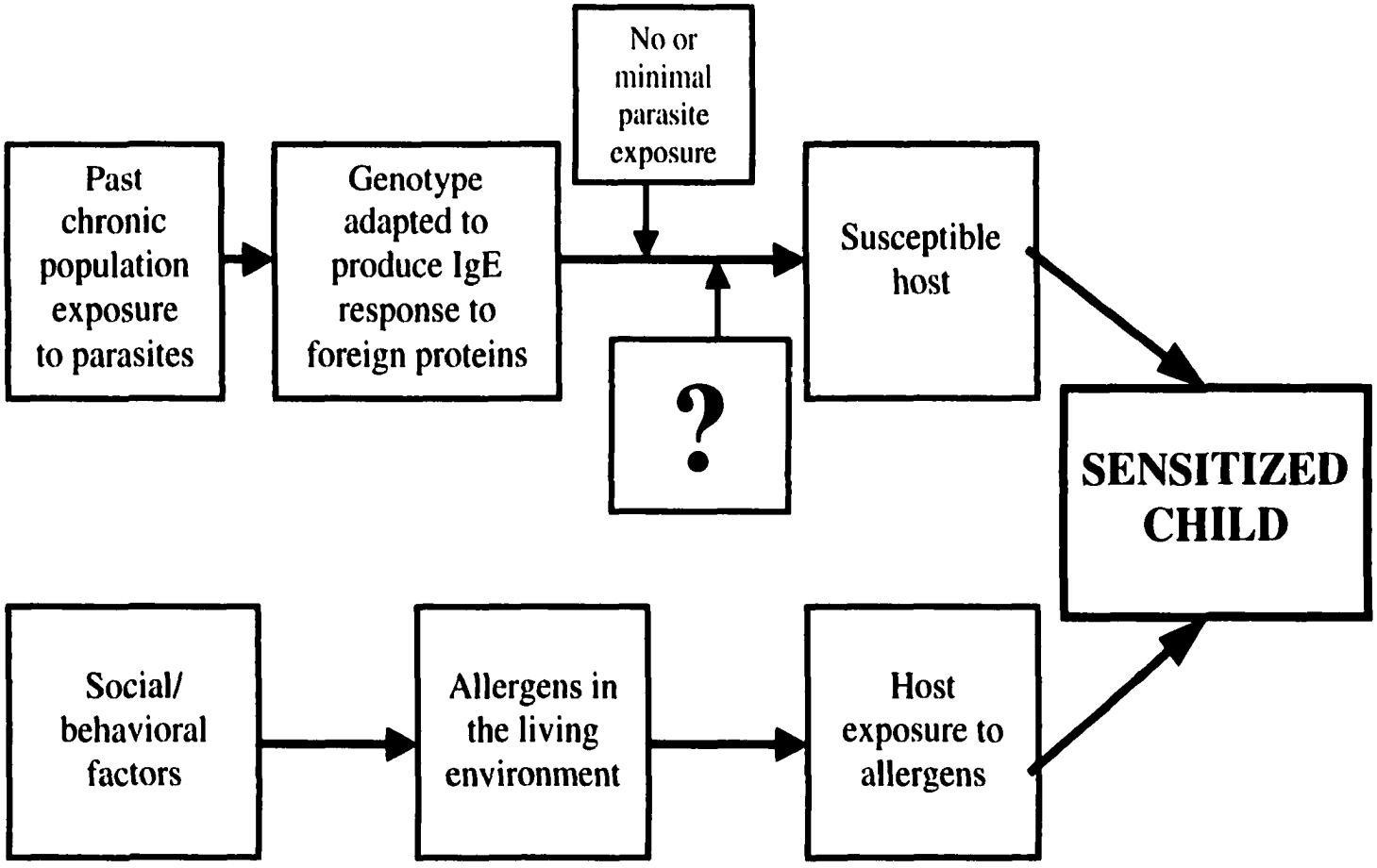
Hypothesis 10c—Asthma will be more common in children in families with less income.

Hypothesis 10d—Asthma will be more common in children whose families have less income or receive government assistance.

Hypothesis 10e—Asthma will be more common in children whose mothers reported prenatally that they were unhappy or ambivalent about their pregnancies.

Not all hypotheses in this set carry equal weight in constructing a model to address the increase in asthma prevalence. Hypothesis 1 is background information. Hypotheses 2, 3, 4, and 9 concern factors thought not to be strong predictors of variation in asthma rates. **The key issues addressed in this research project are represented in hypotheses 5, 6, 7, 8, and 10.** These hypotheses address asthma risk related to maternal reproductive history, age of mothers, maternal obesity, birth anthropometry, and social stressors.

Figure 1. Theoretical model underlying hypotheses predicting incidence of asthma.



Set 2: How asthma affects the lives of children and their families

Figure 2 depicts the model that is the basis of Set 2 hypotheses. The independent variable in these hypotheses is asthma in the child. Outcomes of interest vary. The model and accompanying hypotheses deal with the illness experience of children with asthma. Having asthma, being labeled with the disease and living with its symptoms, changes the lives of children. The overt symptoms of severity are taken, a little unrealistically, as part of the fixed background at this stage and indicated by a darkened box. For parents, asthma changes the way they see their child and how they rear that child. The cultural context shapes family structure, resources (especially income and education of the parents), and family functioning. These factors in turn influence how parents respond to and shape the life of an asthmatic child. The following hypotheses explore ways the lives of children with asthma differ from those of children without asthma. These hypotheses are tested primarily with statistical analyses of quantitative variables supplemented by ethnographic examples.

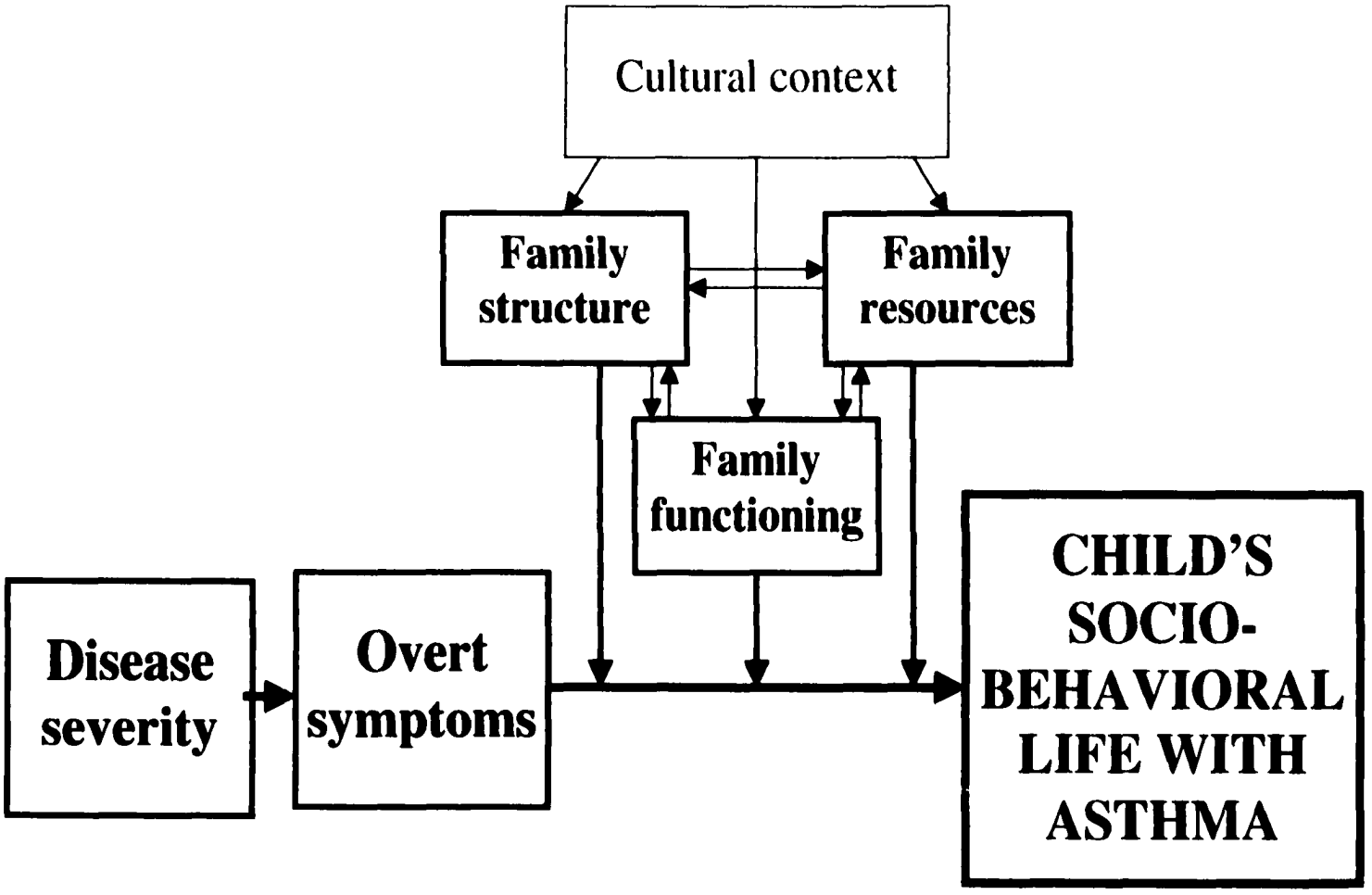
Hypothesis 11—Asthmatic children will be perceived by their mothers as having poorer health and will have more contact with health care professionals and poorer lung function.

Hypothesis 12—Children with asthma will spend less time playing outdoors.

Hypothesis 13—Boys with asthma will be viewed by their mothers as less masculine than healthy boys. Asthma will not affect mothers' perception of their daughters.

Hypothesis 14—Children with asthma will have better developed language skills.

Figure 2. Socio-cultural and familial context in which having asthma changes the life of a child.



Set 3: Factors affecting the ability of families to minimize exposure to secondary triggers, allergens and irritants

Figure 3 depicts the theoretical model driving the Set 3 hypotheses. In the model, climatic conditions, housing, housekeeping, and time spent indoors are independent variables contributing to disease severity through allergen exposure. The Set 3 hypotheses based upon this model are concerned with predicting three of those fours conditions (housing, housekeeping, and time spent indoors), so in the hypotheses are they are dependent variables. The model delineates elements that contribute to severity of asthma in children already sensitized. The first two darkened boxes, indicating that primary sensitization of the child has already taken place and the level of genetic propensity to produce IgE once sensitized, are assumed to be fixed and beyond the control of people at this secondary stage of the disease process. The question-marked box represents unknown elements that might make the disease more severe. Unknowns not addressed in this section but undoubtedly contributing to severity include diet, exercise, and psychosocial stressors.

The other two major categories of factors that modify disease severity are medications and ongoing allergen exposure. Both of those elements are strongly influenced by the family's social environment and the parents' behaviors and choices. A physician prescribes medications, of course, but parents determine frequency of visits to the physician and compliance with the prescribed regimen. Housing, housekeeping, and time spent indoors are influences on ongoing allergen exposure that can be modified. All these factors contribute to ongoing allergen exposure and

the influence of medications within a larger context of parental income, education, competing social pressures, family structure, and cultural attitudes and beliefs. The following hypotheses address this larger context that determines the ability of parents, especially mothers, to manage allergen exposure and medications. Ethnographic observations supplemented by some statistical analyses provide evidence for the hypotheses.

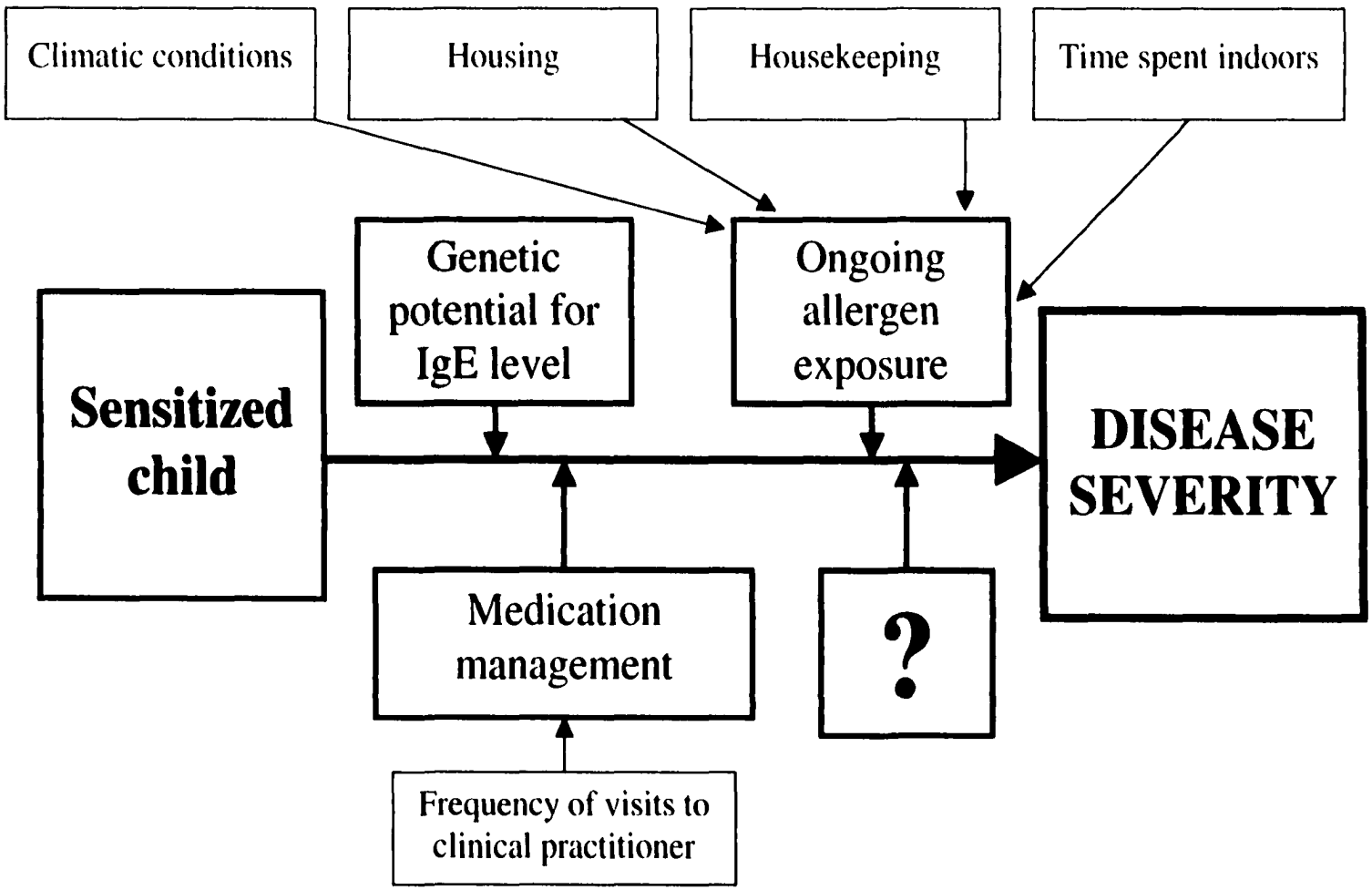
Hypothesis 15—Families living in poverty will be less able to avoid allergens in their home environment.

Hypothesis 16—A subgroup of mothers lacks the awareness and empathy to recognize the needs of their children and improve their health environment.

Hypothesis 17—Fear of crime may be a bigger reason than television that many inner-city children spend more time at sedentary pursuits indoors.

Methods used to collect the data used to test the three sets of hypotheses have been described in this chapter. Hypotheses are analyzed and results discussed in Chapters 6, 7, and 8. Demographic characteristics of the sample are addressed next in Chapter 5.

Figure 3. Theoretical model underlying hypotheses concerning improvement or worsening of asthma severity.



CHAPTER 5
Participant Characteristics

One hundred thirty-six families were interviewed in the University of Oklahoma Maternal and Child Health (OU MCH) follow-up. Five were dropped from the final study, leaving a sample of 131. Four of the eliminated families were dropped because medical information on the children was incomplete or lacking. In one such case, the mother was interviewed in prison and subsequently lost her parental rights before her son could be located. The boy was placed in foster care and his records sealed. Two mothers did not have time to complete the Child Health Questionnaire and the hospital lost their children's medical charts. Another interview had to be eliminated after the interviewer lost most of the records in a move. A last child was not included, even though records on him are complete, because he is an extreme outlier. He weighted only 675 grams at birth and is profoundly retarded.

The charts of discrete and descriptive statistics on the following pages (Tables 1-5) give the basic social and demographic profile of the participants in the original OUHSC Pregnancy Study, the OU MCH Follow-up subgroup, and the OU MCH children identified as asthmatic. Table 1 is particularly useful for identifying bias in the families that were available for the follow-up. The OU MCH subgroup profiles are similar to the original study families in such socioeconomic indices as household income and mothers' education. A difference that stands out is that more of the mothers in the follow-up subgroup were African-American than in the overall cohort (43.5 versus 31.1 percent), with correspondingly fewer being European-Americans

(48.1 versus 62.0 percent). African-American women may have been easier to contact again if they continued to use the University Hospital clinic for regular medical care. They may also have been less likely to leave the Oklahoma City area, as many had extended families there. Women followed up on in the OU MCH sample were also better educated. In the OUHSC Pregnancy Study, 57 percent of the women had completed high school before their pregnancy. By contrast, 70 percent of the OU MCH mothers had completed high school by the time they were pregnant with the index child.

Ten of the children in the study did not live with their mothers, so they and their mothers were interviewed separately. In four of those cases, the mother was incarcerated. Those children were living either with their fathers or extended family. Fathers were rearing another three of the children. Extended families had taken over care of two children whose mothers were drug addicts. Two of the mothers' interviews were very limited in time. The only mother that was not interviewed had been murdered less than a year before the follow-up interviews. That child's grandmother provided health information on both her daughter and granddaughter, and recent anthropometric measurements on the mother were available from her medical chart.

Thirty-one of the 131 children, 23.7 percent, were identified as having asthma after infancy. That percentage seems shockingly high at first, given that a CDC report on all fifty states showed Oklahoma tied with two other states (Florida and West Virginia) for the lowest forecasted prevalence of self-reported asthma, 5.8

percent for all age and demographic groups (CDC, 1998a). But the children targeted by this study fit a high-risk profile. They are poor, mostly urban, and more than half the children belong to an ethnic minority (although nearly as many European-American children had asthma as other children). Studies of low-income city children in other regions have found comparable asthma rates.

Table 1. Discrete descriptive statistics.

		1988-91 1208 Pregnancy Cohort Dyads		1995-96 131 OU MCH Study Dyads		1995-96 31 (23.7% of MCH) Children with Asthma		
		#	%	#	%	#	% of 31	% of MCH
SEX	Boys	621	51.4	64	48.9	16	51.6	25.0
	Girls	587	48.6	67	51.1	15	48.4	22.4
MOTHER'S ETHNICITY	European-American [1]	749	62.0	63	48.1	13	41.9	20.6
	African-American [1]	378	31.3	57	43.5	16	51.6	28.1
	Native American [1]	33	2.7	5	3.8	2	6.5	40.0
	Hispanic [1]	41	3.4	4	3.1	0	0	0
	Other [1]	7	0.5	2	1.5	0	0	0
HOUSEHOLD COMPOSTION	T1 Mother married/ living with partner [2]	583	48.3	52	40.6	8	26.7	15.4
	T1 Mother single [2]	625	51.7	76	59.4	22	73.3	28.9
	T1 Extended family in mother's household [3]			46	36.2	15	50.0	32.6
	T3 Mother married/ living with partner [2]	N/A	N/A	72	55.4	14	45.2	19.4
	T3 Mother single [2]	N/A	N/A	58	44.6	17	54.8	29.3
	T3 Extended family in mother's household [3]	N/A	N/A	25	19.1	6	19.4	24.0
	T3 Extended family in child's household [3]	N/A	N/A	32	24.4	8	25.8	25.0
	T3 Child living apart from mother [3]	N/A	N/A	10	7.6	4	12.9	40.0
	T3 Adult male in child's household [4]	N/A	N/A	80	61.1	19	61.3	23.8
	T3 Child living with both biological parents	N/A	N/A	61	46.2	11	35.5	18.0

Table 2. Discrete descriptive statistics, continued.

		1988-91 1208 Pregnancy Cohort Dyads		1995-96 131 OU MCH Study Dyads		1995-96 31 (23.7% of MCH) Children with Asthma		
		#	%	#	%	#	% of 31	% of MCH
MOTHER'S EDUCATION	T1 Less than 12 years schooling [5]	221	43.3	39	30.5	9	29.0	23.1
	T1 At least 12 years schooling [5]	684	56.7	89	69.5	22	71.0	24.7
	T1 Greater than 14 years schooling [5]	44	3.6	5	3.9	2	6.7	40.0
	T3 Less than 12 years schooling [5]	N/A	N/A	36	28.1	7	22.6	19.4
	T3 At least 12 years schooling [5]	N/A	N/A	92	71.9	24	77.4	26.1
	T3 Greater than 14 years schooling [5]	N/A	N/A	12	9.4	3	9.7	25.0
	T1 Less than 18 years old at child's birth	74	6.1	7	5.3	3	9.7	42.9
INCOME SOURCES	T1 Household below poverty line [6]	941	78.4	101	78.9	25	83.3	24.8
	T1 Mother employed	370	30.7	46	35.9	14	46.7	30.4
	T1 No wage earner in household	249	20.6	22	17.5	3	10.0	13.6
	T3 Household below poverty line [6]	N/A	N/A	68	57.1	13	41.9	19.1
	T3 Mother employed	N/A	N/A	67	51.1	19	61.3	28.4
	T3 Household receives govt assistance [7]	N/A	N/A	50	39.4	11	36.7	22.0
	T3 No wage earner in household	N/A	N/A	38	29.0	7	22.6	18.4
BIRTH	Preterm [8]	108	8.9	8	6.1	3	9.7	37.5
	Term [8]	1100	91.1	123	93.1	28	90.3	22.8
	Low birth weight [9]	92	7.6	9	6.9	3	9.7	33.3
	Normal birth weight [9]	1085	89.8	119	90.8	28	90.3	23.5
	Macrosomic [9]	32	2.6	3	2.3	0	0	0

Table 3. Continuous descriptive statistics for 1208 OUHSC Pregnancy Study mother-infant dyads

	Average	Range	Std Dev	Skewness	Mode
T2 Age of mother at child's birth	23.0	13.7-41.3	5.0	0.9	20
T1 Mother's children older than index child	1.3	0-8	1.3	1.3	0
T1 Years of education completed by mother [5]	11.4	0-20	1.8	-0.4	12
T1 Mother's income, if employed [10]	N/A	N/A	N/A	N/A	N/A
T1 Household income [11]	10,869	200-72,000	8,563	2.7	9,600
T1 Mother's NAM, if employed with NAM [12]	32.3	2-97	18.0	0.9	29
T1 NAM of mother's partner, if in household and employed [13]	37.3	3-99	19.0	0.7	32
T1 Highest NAM in family, if > 0	42.9	2-99	20.7	0.5	32
T2 Birth weight of child in grams	3318.9	360-5800	619.8	-0.60	3200
T2 Gestational age of child in weeks	38.8	20-43	2.1	-3.3	40

Table 4. Continuous descriptive statistics for 131 OU MCH mother-child dyads

	Average	Range	Std Dev	Skewness	Mode
T3 Age of child at home interview	5.8	4.2-8.3	0.8	0.24	N/A
T3 Age of mother at home interview	30.8	21.1-45.7	5.2	0.66	N/A
T2 Age of mother at child's birth	25.0	15.4-38.5	5.1	0.61	N/A
T2 Mother's children older than index child	1.4	0-8	1.3	1.4	0
T3 Total number of children born to mother	3.0	1-9	1.4	1.9	3
T1 Years of education completed by mother [5]	11.8	2-16	1.6	-1.53	12
T1 Household income [11]	10,009	0-63,000	8,495	2.9	N/A
T1 Mother's NAM, if employed [12]	32.3	3-97	22.6	0.09	41
T1 NAM of mother's partner, if in household and employed [13]	38.4	13-82	15.8	0.5	32
T1 Highest NAM in family, if > 0	49.2	2-97	22.6	0.09	41
T3 Years of education completed by mother [5]	12.2	6-17	1.9	-0.07	12
T3 Mother's annual gross income, if employed [11]	11,378	500-48,000	6942	2.6	N/A
T3 Household annual gross income [11]	18,173	0-125,000	15,232.4	3. 8	14,400
T3 Mother's NAM, if employed [12]	33.8	3-88	19.5	1.0	N/A
T3 NAM of mother's partner, if in household and employed [13]	45.4	14-87	17.3	0.4	41
T3 Highest NAM in family, if > 0 [14]	46.5	19-87	15.7	0.5	41
T2 Birth weight of child	3299.4	1850-4860	543.0	0.1	3330
T2 Gestational age of child	39.1	33-42	1.6	-1.0	39

Table 5. Continuous descriptive statistics for 31 OU MCH asthmatic children and their mothers

	Average	Range	Std Dev	Skewness	Mode
T3 Age of child at home interview	5.8	4.6-7.6	0.7	0.4	N/A
T3 Age of mother at home interview	29.0	22.3-38.9	8.9	0.8	N/A
T1 Age of mother at child's birth	23.2	16.5-33.6	4.02	0.8	N/A
T2 Mother's children older than index child	1.0	0-3	1.0	0.7	1
T3 Total number of children born to mother	2.6	1-4	1.0	0.6	2
T1 Years of education completed by mother [5]	11.8	2-16	1.6	-1.5	12
T1 Household income [11]	8,882	0-35,000	7,740	2.0	N/A
T1 Mother's NAM, if employed [12]	34.6	15-97	21.6	2.0	28
T1 NAM of mother's partner, if in household and employed [13]	38.5	13-61	13.7	-0.2	32
T1 Highest NAM in family, if > 0	49.6	15-97	20.0	0.2	41
T3 Years of education completed by mother [5]	12.5	9-17	1.8	0.6	12
T3 Mother's annual gross income, if employed [10]	12,594	5,000-48,000	9,687	3.1	9,000
T3 Household annual gross income [11]	16,886	0-72,700	13,522	3.0	20,000
T3 Mother's NAM, if employed [12]	37	14-82	15.9	1.5	28
T3 NAM of mother's partner, if in household and employed [13]	40.7	14-87	17.4	1.4	38
T3 Highest NAM in family, if > 0 [14]	46.5	32-87	16.8	2.0	32
T2 Birth weight of child	3122.6	1850-4172	505.8	-0.8	N/A
T2 Gestational age of child	38.8	33-42	1.8	-1.6	39

Variable explanations for Tables 1-5

Cases where variables or percentages add to less than the column total are the result of missing values.

(1) Mothers identified their own ethnicity. In a few cases, the ethnicity of the child differs from the mother, but the difference is trivial in analyses. Ethnicity of only the mothers was available in the original pregnancy study, so using mothers' ethnicity has the advantage of increasing comparability between the original cohort and the follow-up participants. The "other" category includes people of Asian descent and people of mixed heritage.

(2) Distinguishes whether the mother is living with a male partner, regardless of marital status. Women married but voluntarily separated are counted as single. Women married but separated involuntarily (i.e., husband is incarcerated) are recorded as married.

(3) In a few cases, the biological mother and index child live in separate households. The mother's other biological children may or may not live with her. Note that socioeconomic variables (income and NAM) do not apply to the index child's household if the child does not live with its mother.

(4) Distinguishes whether the child lives at least half time in a household with any adult man. He may be a relative or not and need not be a father figure (i.e., may be a grandfather or uncle).

(5) Mother's education includes only the years of schooling she actually completed. A certificate of General Educational Equivalency (GED) is recorded as 12 years only if followed by higher education.

(6) Households classified as above or below the poverty line are based on the following 1995 guidelines (Anonymous, 1995):

Size of Family Unit	48 Contiguous States and D.C.
1	$ 7,470
2	10,030
3	12,590
4	15,150
5	17,710
6	20,270
7	22,830
8	25,390

For each additional person, add $2,560.

(7) Whether the mother's household receives government support or assistance. Includes AFDC, Social Security, disability, housing assistance, and/or food stamps, but does not include Medicaid or daycare assistance. Incarcerated mothers are counted as receiving government support.

(8) Using categories traditional in fetal growth epidemiology, preterm is born before 37 weeks; term indicates a gestational age of at least 37 weeks.

(9) Using categories traditional in fetal growth epidemiology, low birth weight (LBW) is <=2,500g; normal birth weight is 2,499-4,499g; and macrosomia is >=4,500g.

(11) Mother's annual gross income includes only earned wages from employment.

(12) Total annual gross income of the mother's household. Includes the mother's and her partner's earned income, child support, government support including AFDC, Social Security, disability, and food stamps. Does not include income of other relatives or friends mother may live with, government housing assistance, Medicaid, or government daycare assistance.

(13) NAM code for the occupational status of the mother if she is employed. Job scores range from 1 to 100, with higher values indicating higher social status.

(14) NAM code for occupational status of mother's partner, if living in the same household with her. Job scores range from 1 to 100, with higher values indicating higher social status.

(15) Includes only households where at least one person is employed. T1 highest household NAM can be that of the mother, her partner, or either of her parents. T3 highest household NAM is the higher of mother's or her partner's NAM codes.

CHAPTER 6
Set 1 Hypotheses—Risk Factors for Onset

Heredity, Living Environment, and Smoking

Hypothesis 1—Children with asthmatic relatives will have more asthma.

ANALYSES

Contingency tables compare rates of asthma among children with and without at least one close relative with asthma (Table 7). A family history of asthma associates powerfully with asthma in index children. A child with a least one sibling, parent, aunt, uncle, or grandparent with asthma is 5.4 times (33.8 versus 6.3 percent) more likely to have asthma than a child with no close asthmatic relative ($p=0.001$). Among African-American children, 9.52 percent have asthma even if they have no relative with asthma. Similarly, 9.09 percent of girls have asthma, even with no family history of asthma. By contrast, only 3.85 percent of boys with no family history have asthma. The relative risk for a boy with an asthmatic relative is 10.8. Of children with asthmatic mothers, 48.15 percent had been diagnosed with asthma, 2.8 times more than children whose mother did not have asthma.

Table 7.

T3 FAMILY HISTORY OF ASTHMA			Percent with Asthma	χ^2 p-value
ASTHMA IN ANY RELATIVE				
ALL FAMILIES	N=48	No asthma in family	6.25	
	N=80	Asthmatic relative	33.75	0.001
EUROPEAN-AMERICANS	N=23	No asthma in family	4.35	
	N=38	Asthmatic relative	28.95	0.019
AFRICAN-AMERICANS	N=21	No asthma in family	9.52	
	N=35	Asthmatic relative	40.00	0.015
FAMILIES OF GIRLS	N=22	No asthma in family	9.09	
	N=44	Asthmatic relative	27.27	0.089
FAMILIES OF BOYS	N=29	No asthma in family	3.85	
	N=33	Asthmatic relative	41.67	0.001
ASTHMA IN MOTHER				
ALL MOTHERS	N=93	Mom not asthmatic	17.20	
	N=27	Mom asthmatic	48.15	0.001
EUROPEAN-AMERICANS	N=38	Mom not asthmatic	10.53	
	N=18	Mom asthmatic	44.44	0.004
AFRICAN-AMERICANS	N=44	Mom not asthmatic	22.73	
	N=9	Mom asthmatic	55.56	0.046
MOTHERS OF GIRLS	N=49	Mom not asthmatic	18.37	
	N=11	Mom asthmatic	36.36	0.190
MOTHERS OF BOYS	N=44	Mom not asthmatic	15.91	
	N=16	Mom asthmatic	56.25	0.002

DISCUSSION

As expected, family history of asthma is a major risk factor for asthma in the OU MCH children. There appears to be a highly heritable component to asthma in the study population, an observation consistent with other research on asthma

epidemiology. This is important background information but does little to advance understanding of why asthma rates are increasing. Studies capable of pinpointing particular candidate genes have enormous value for identifying which people are more vulnerable and uncovering the elements that come together to bring on asthma.

Comparing African-American to European-American children with asthma, more African-Americans (9.5 percent) had no prior family history of asthma. This could reflect simply the generally higher prevalence in African-Americans but also less likelihood of the disease having been diagnosed in older generations. Alternately, it could mean prevalence of the asthmatic phenotype is increasing fastest in that group, an interpretation consistent with trends seen in national data. The relative risk for boys with an asthmatic relative to those without was 10.8 ($p=0.001$) compared to only 3.0 for girls ($p=0.089$). Sample sizes are too small to be definitive, but the lower relative risk associated with family history for girls suggests environmental factors may have greater influence on onset of asthma in girls.

Hypothesis 2—Cleanliness and condition of homes will not explain the variation in asthma among children.

ANALYSES

Interviewers visually rated the cleanliness, clutter, and neatness of the living areas in each house and the room where each index child slept. Ordinal scores range from 1 to 10, with higher numbers indicating dirtier, more cluttered, or less neat houses. Student's t tests compare means and standard deviations of each measure of housekeeping for children with and without asthma. Results are shown in Tables 8 and 9. The relationship between asthma and cleanliness of the house or sleeping area does not approach statistical significance. Similarly, cleanliness of the floors and neatness of homes do not associate with asthma. Of the assessments, clutter associates strongest with asthma, with asthma in children living in homes 11 percent more cluttered than non-asthmatic children ($p=0.133$). In the children's sleeping areas, amount of clutter is close to statistical significance for the overall sample at $p=0.053$, with the rooms of asthmatic children 17 percent more cluttered than the rooms of other children.

Because clutter in homes, and particularly in sleeping areas, associates strongest with asthma, the effects of clutter are broken down further by ethnicity and sex of children. Clutter in the living areas approaches statistical significance for African-Americans and girls ($p=0.094$ and $p=0.078$, respectively). In sleeping areas as well, the relationship is strongest for African-Americans and girls.

Contingency tables show that prevalence of asthma is four times greater for

children living in carpeted houses than in houses with wooden, vinyl, or linoleum floors (Table 10). The relationship does not reach statistical significance ($p=0.091$), however, probably because only sixteen children lived in homes without carpeting. However, only one child with a hard floor had been diagnosed as having asthma whereas twenty-eight children living with carpet had.

Homes of children in the OU MCH sample were built between 1905 and 1985, the average being built in 1955 (Table 11). Asthmatic children lived in homes on average five years older, though the difference approached statistical significance only for girls ($p=0.086$).

The observation that clutter associates with asthma primarily in girls and African-Americans prompts comparison of cleanliness, clutter, neatness, and cleanliness of floors by sex of the child for all homes and for the two major ethnic groups (Table 12). In the entire sample and particularly in European-American homes, rooms of girls were dirtier, more cluttered, and messier than boys' rooms and had dirtier floors. No difference was observed in the rooms of girls and boys in African-American homes.

Table 8.

T3 CONDITION OF LIVING AREAS			Mean	Std. Dev.	T-test p-value
CLEANLINESS OF LIVING AREAS IN CHILD'S HOME					
ALL HOMES	N=98	Child not asthmatic	4.7041	2.3734	
	N=29	Child asthmatic	5.0690	2.5764	0.239
CLEANLINESS OF FLOOR IN LIVING AREAS IN CHILD'S HOME					
ALL HOMES	N=97	Child not asthmatic	4.8866	2.4362	
	N=29	Child asthmatic	5.3103	2.5228	0.208
NEATNESS OF LIVING AREAS IN CHILD'S HOME					
ALL HOMES	N=97	Child not asthmatic	4.7835	2.4076	
	N=29	Child asthmatic	5.2414	2.4298	0.186
CLUTTEREDNESS OF LIVING AREAS IN CHILD'S HOME					
ALL HOMES	N=97	Child not asthmatic	5.0309	2.3024	
	N=29	Child asthmatic	5.5862	2.4859	0.133
EUROPEAN-AMERICANS	N=48	Child not asthmatic	4.9375	2.1968	
	N=12	Child asthmatic	5.2500	2.0944	0.329
AFRICAN-AMERICANS	N=40	Child not asthmatic	4.9000	2.2960	
	N=15	Child asthmatic	5.8667	2.6421	0.094
HOMES OF GIRLS	N=52	Child not asthmatic	5.1731	2.4150	
	N=14	Child asthmatic	6.2143	2.3916	0.078
HOMES OF BOYS	N=45	Child not asthmatic	4.8667	2.1805	
	N=15	Child asthmatic	5.0000	2.5071	0.422

Table 9.

T3 CONDITION OF CHILD'S SLEEPING AREA			Mean	Std. Dev.	T-test p-value
CLEANLINESS OF CHILD'S SLEEPING ROOM					
ALL HOMES	**N=94**	**Child not asthmatic**	5.1596	2.3155	
	N=29	**Child asthmatic**	5.3448	2.2878	0.353
CLEANLINESS OF FLOORS IN CHILD'S SLEEPING ROOM					
ALL HOMES	**N=95**	**Child not asthmatic**	5.3474	2.4615	
	N=29	**Child asthmatic**	5.4828	2.4585	0.378
NEATNESS OF CHILD'S SLEEPING ROOM					
ALL HOMES	**N=95**	**Child not asthmatic**	5.1684	2.4739	
	N=29	**Child asthmatic**	5.6207	2.6378	0.199
CLUTTEREDNESS OF CHILD'S SLEEPING ROOM					
ALL HOMES	**N=95**	**Child not asthmatic**	5.1579	2.5362	
	N=29	**Child asthmatic**	6.0345	2.5563	0.053
EUROPEAN-AMERICANS	**N=48**	**Child not asthmatic**	5.1875	2.2939	
	N=12	**Child asthmatic**	5.7500	2.0944	0.222
AFRICAN-AMERICANS	**N=38**	**Child not asthmatic**	4.9474	2.7602	
	N=15	**Child asthmatic**	6.2000	2.9326	0.075
HOMES OF GIRLS	**N=51**	**Child not asthmatic**	5.3922	2.4745	
	N=14	**Child asthmatic**	6.5714	2.5933	0.062
HOMES OF BOYS	**N=44**	**Child not asthmatic**	4.8864	2.6078	
	N=15	**Child asthmatic**	5.5333	2.5033	0.203

Table 10.

T3 TYPE OF FLOORING IN LIVING AREAS OF CHILD'S HOME			Percent with Asthma	χ^2 p-value
ALL HOMES	N=111	Carpet	25.23	
	N=16	Hard floors	6.25	0.091

Table 11.

T3 YEARS HOMES BUILT BASED ON COUNTY TAX ASSESSOR RECORDS			Mean	Std. Dev.	T-test p-value
ALL HOMES	N=75	Child not asthmatic	1955.75	17.27	
	N=20	Child asthmatic	1950.10	21.46	0.111

Table 12.

T3 CONDITION OF LIVING AREAS BY SEX OF THE CHILD			Mean	Std. Dev.	T-test p-value
CLEANLINESS OF CHILD'S SLEEPING ROOM					
ALL HOMES	**N=64**	**Girls**	5.5000	2.2039	
	N=59	**Boys**	4.8814	2.3787	0.068
EUROPEAN-AMERICANS	**N=27**	**Girls**	5.2963	2.3174	
	N=33	**Boys**	4.5758	2.3053	0.117
AFRICAN-AMERICANS	**N=30**	**Girls**	5.5333	1.9954	
	N=23	**Boys**	5.2609	2.5445	0.332
NEATNESS OF CHILD'S SLEEPING ROOM					
ALL HOMES	**N=65**	**Girls**	5.5385	2.5005	
	N=59	**Boys**	4.9831	2.5085	0.110
EUROPEAN-AMERICANS	**N=27**	**Girls**	5.8148	2.4185	
	N=33	**Boys**	4.9091	2.2131	0.068
AFRICAN-AMERICANS	**N=30**	**Girls**	5.2000	2.5650	
	N=23	**Boys**	5.1304	2.9742	0.464
CLUTTEREDNESS OF CHILD'S SLEEPING ROOM					
ALL HOMES	**N=65**	**Girls**	5.6462	2.5275	
	N=59	**Boys**	5.0508	2.5760	0.098
EUROPEAN-AMERICANS	**N=27**	**Girls**	5.9630	2.2614	
	N=33	**Boys**	4.7576	2.1218	0.019
AFRICAN-AMERICANS	**N=30**	**Girls**	5.2667	2.7029	
	N=23	**Boys**	5.3478	3.0690	0.460
CLEANLINESS OF THE FLOORS IN CHILD'S HOME					
ALL HOMES	**N=66**	**Girls**	5.3485	2.4337	
	N=60	**Boys**	4.5833	2.4307	0.040
EUROPEAN-AMERICANS	**N=28**	**Girls**	4.8214	2.4654	
	N=32	**Boys**	4.1875	2.4421	0.161
AFRICAN-AMERICANS	**N=30**	**Girls**	5.7000	2.1359	
	N=25	**Boys**	5.0400	2.5080	0.148

DISCUSSION

Cleanliness, clutter, and neatness in homes were rated by several different interviewers, minimizing the possibility of bias by any one rater. Additionally, a different person from the one that interviewed the mother conducted living environment ratings. Therefore, the interviewer rating the environment rarely knew until after the interview and ratings were already recorded whether the child was asthmatic.

Few of the measures of housing conditions are statistically significant or have more than a small magnitude of effect on asthma rates. This finding is consistent with previous research included in the review chapter and the idea that host characteristics are more important than allergen exposure in explaining the variance in who develops asthma. However, the differences between means are all in the direction that would be expected if allergen exposure had some effect. That is, homes of asthmatic children were somewhat less clean, more cluttered, and less neat. For two equally susceptible children, differences in level of sustained allergen exposure in their homes could make the difference as to which becomes ill. Clean houses may help some children avoid sensitization, and dirty houses may increase risk to susceptible children. Sources of host susceptibility explain more variance, but allergen exposure is an essential step in developing asthma.

The intent in having interviewers distinguish clutter and neatness as well as cleanliness was to help them mentally separate these characteristics, the assumption

being that cleanliness was truly most important. In analyses, however, clutter produces the strongest effect. Cluttered surroundings may harbor dust mites, a problem that cannot be remedied by simply vacuuming the carpet in the middle of the room or dusting flat open surfaces. A room that has been vacuumed and dusted on visible surfaces may appear clean but still have high dust mite load hidden in a multitude of objects. The standard advice that allergic people should remove "dust catchers" such as stuffed animals and knickknacks does seem appropriate.

One published report found children with brothers had less asthma (Svanes et al., 1999). The authors are proponents of the notion that dirt and viral exposures are protective and suggest boys are probably dirtier than girls. This assumption is not consistent with findings here. In this sample, boys slept in 13 percent cleaner rooms than girls ($p=0.068$). Floors throughout the homes of boys were 17 percent cleaner ($p=0.040$). Perhaps boys are more independent, spend more time away from their mothers, and therefore hamper housekeeping less. Particularly in European-American homes, boys' rooms were 25 percent less cluttered than girls' rooms ($p=0.019$). No gender difference in the clutter of children's rooms was detected in African-American families. European-American parents may be more indulgent in buying toys and decorative objects for little girls. Toys bought for boys are more of the type kept outdoors. Many little girls get dolls and stuffed animals while boys get bicycles and basketballs. Not only were rooms of European-American girls more cluttered than those of European-American boys or African-American children of

either sex, but among European-American girls those with asthma slept in rooms 22 percent more cluttered as measured in this study (p=0.062).

Measurements of the living environment were cross-sectional with assessment of asthma prevalence at follow-up. If mothers of asthmatic children had responded to their children's disease by cleaning up the home environment, then the difference between homes of asthmatic and non-asthmatic children may have been greater before the asthmatic children were diagnosed. Nevertheless, no compensatory housekeeping on the part of mothers with asthmatic children was detected in this study.

Asthmatic children lived in houses on average six years older, but the difference was too small to be statistically significant. Few children with hard floors had asthma. Only 16 children lived in homes without carpeting. Of those without carpeting, only 6.3 percent had asthma, compared to 25.2 percent with carpeting. On the other hand, the protective value of hard floors could be confounded by underdiagnosis of asthma. Families in homes without carpeting had $5,200 lower annual incomes (38 percent less) than families with carpet (p=0.039), so their children might have less access to medical care. The chi-squared p-values of the relationship between flooring type and asthma are not smaller than alpha (p=0.091). Chi-squared p-values for flooring type are not smaller than alpha, because the sample of homes without carpeting is too small to have much power.

In sum, living conditions indicative of high allergen exposure are not totally inconsequential in development of asthma but do not explain a large part of the

variance in asthma rates among children. This finding is consistent with the model depicted in Figure 1 of Chapter 4 that posits allergen exposure is a necessary but not sufficient cause for the initiation of asthma in children. Host characteristics addressing which children are susceptible have greater explanatory value.

Hypothesis 3—Maternal smoking will not increase risk of asthma in children.

ANALYSES

Nonsmokers in the T1 analyses include women that never smoked, those that quit before they became pregnant, and those that quit by the end of the third trimester. A mother is classified as having smoked prenatally if she reported continuing to smoke after the first trimester.

Mothers of asthmatic children were more likely to be nonsmokers both prenatally and at the follow-up interview (Table 13). Asthma is 40 percent more prevalent among children whose mothers did not smoke while they were pregnant.

The same relationship is seen between asthma in children and whether their mothers smoked at the time of the follow-up interview. The negative association between mother's smoking and asthma approaches statistical significance (0.062).

Because asthmatic women might be less likely to smoke and asthma in mothers is highly predictive of asthma in their children, the contingency tables of mothers' smoking by asthma in their children are repeated, separating out mothers without asthma and mothers with asthma themselves. Among children with non-asthmatic mothers, smoking is not related to asthma. Among children of asthmatic mothers, maternal smoking is negatively associated with asthma. P-values come slightly short of statistical significance for prenatal smoking by asthmatic mothers but significant for mothers smoking at the time of the follow-up interview ($p=0.035$).

Table 13.

WHETHER MOTHER SMOKED, ALL MOTHERS			Percent with Asthma	χ^2 p-value
T1 MOTHER SMOKED DURING PREGNANCY				
ALL MOTHERS	**N=75**	**Non smoker**	26.67	
	N=53	**Smoker**	18.87	0.305
T3 MOTHER SMOKED AT FOLLOW-UP				
ALL MOTHERS	**N=62**	**Non smoker**	30.65	
	N=66	**Smoker**	16.67	0.062
T1 MOTHER SMOKED DURING PREGNANCY				
NON-ASTHMATIC MOTHERS	**N=56**	**Non smoker**	16.07	
	N=34	**Smoker**	17.65	0.846
T3 MOTHER SMOKED AT FOLLOW-UP				
NON-ASTHMATIC MOTHERS	**N=46**	**Non smoker**	19.57	
	N=45	**Smoker**	15.56	0.615
T1 MOTHER SMOKED DURING PREGNANCY				
ASTHMATIC MOTHERS	**N=16**	**Non smoker**	62.50	
	N=11	**Smoker**	27.27	0.072
T3 MOTHER SMOKED AT FOLLOW-UP				
ASTHMATIC MOTHERS	**N=13**	**Non smoker**	69.23	
	N=14	**Smoker**	28.57	0.035

DISCUSSION

Smoking by mothers prenatally or at follow-up appears to be slightly protective against asthma in the OU MCH children. Clearly, at least, it is not a risk factor. This finding runs counter to intuition at first but may make sense when considered in terms of how the immune system responds to smoking. As noted in the literature review in Chapter 2, some previous studies failed to find higher asthma rates among children of smoking mothers (von Mutius et al., 1994b; Strachan,

Butland, and Anderson, 1996) or found wheeze that resolved by age three or four (Stein et al., 1999; Tariq et al., 1998). Bearing in mind that asthma is a Th2-dominated immune disease and that a healthy pregnancy is Th2-dominant, it may be that smoking promotes a Th1 response or interferes with full Th2-type expression. Smoking retards fetal growth and smoking women are more likely to miscarry (Gocze, Szabo, and Freeman, 1999; Pattinson, Taylor, and Pattinson, 1992). Th1 activity is also associated with miscarriage. (The immunology of pregnancy is discussed more fully in the section on "Maternal Characteristics versus Viral Exposures".) Smoking also alters the hormonal balance in women. There is some disagreement on whether the main effect is reduction of estrogens (Baron, Vecchia, and Levi, 1990; Key et al., 1996; Spangler, 1999) or increase in androgens (Law et al., 1997). Regardless, smoking alters the ratio of estrogens to androgens in women. This change would be expected to tip immune function toward Th1-type cellular activity. Few published studies address Th1 versus Th2 response to smoking.

Lung growth and atopy are both important in asthma. Prenatal and early environmental exposure to tobacco smoke clearly retard lung growth and reduce early lung function (Corbo et al., 1996; Gilliland et al., 2000; Stick et al., 1996; Young et al., 2000). Parental smoking also contributes to wheeze, perhaps because of retarded lung growth (Ehrlich et al., 1996; Morgan and Martinez, 1992; Stoddard and Miller, 1995). Findings linking smoke exposure to atopy are inconsistent. Kulig et al. (1999) find more sensitization to food allergens by age three among children exposed to smoke. Studying the Inuit, Hemmelgarn and Ernst (1997) found 80 percent of

women smoked during pregnancy and even 32 percent of children smoked, yet the Inuit had strikingly low prevalence of atopy (5 percent in children). Smoking increases inflammation in the lower respiratory tract (Floreani and Rennard, 1999). Majori and coworkers (Majori et al., 1999) identified a Th1-type immune response and reduced IL-4 (the cytokine most associated with allergy) among patients with chronic obstructive pulmonary disease (COPD) brought on by smoking. More Th1 activity in COPD patients may be the determinant of how their bodies responded to smoking and which disease they manifested rather than a direct response to smoking. The Th2 phenotype has been found to predominate among the subset of smokers with chronic bronchitis (Mattoli et al., 1997). So tobacco smoke exposure is clearly related to reduced lung growth and pulmonary function in children, but its precise role in how an infant's immune system develops and atopy have not been fully deciphered.

Regardless, maternal smoking did not increase risk of asthma in the OU MCH children. In order to control for the possibility that mothers with a history of asthma themselves were less likely to smoke, asthma rates among children of smokers and nonsmokers were subdivided by whether the mother had asthma. Not only were asthmatic mothers no less likely to smoke, but maternal smoking appears particularly protective for children with maternal history of asthma. The protective effect may be real, particularly if smoking reduces atopy. On the other hand, smoking may have induced asthma-like symptoms such as wheezing in mothers that would not otherwise have wheezed and may not carry a genotype likely to lead to asthma in children. In

other words, some of the smoking mothers labeled as asthmatic may have had non-atopic wheezing brought on by smoking itself and that did not increase risk for their children. If so, smoking may confound prevalence of inheritable asthma in mothers. Smoking mothers might have been less likely to have their children evaluated for respiratory symptoms. Non-smokers may have generally more health awareness and be more likely to recognize symptoms in their children and take them to physicians. In addition, mothers with a habit known to hurt child health might not want to face up to knowing they were damaging their children. This is possible, though it does not fit the ethnographic evidence. Mothers that smoked took particular interest in our lung function testing and generally seemed anxious and interested to know whether their smoking might be harming their children.

Evidence in the literature is abundant that passive smoke exposure worsens symptoms for children with asthma. Maternal smoking retards fetal growth and may permanently alter lung development. Smoking as a prophylaxis for asthma would be disastrous. It is important, though, in building a model to decipher why asthma rates are increasing to recognize that smoking by mothers will not fully account for the increase.

Viral Exposure versus Maternal Age and Reproductive History

Analyses of Hypotheses 4, 5, and 6 are presented sequentially, followed by a discussion pulling together the issues in all three.

Hypothesis 4—Exposure to more people, as a surrogate for viral exposure, will not predict asthma in children.

Hypothesis 4a—Asthma prevalence among children will not associate with time spent in group daycare.

Hypothesis 4b—Asthma prevalence among children will not associate with number of people living in the household at birth or at follow-up.

ANALYSES

Which children ever attended daycare has a modest association with asthma rates (Table 14). Asthma was 42 percent more prevalent among children that ever attended daycare compared to those that had never been in daycare, but this relationship does not reach statistical significance (p=0.291). Residuals of the number of months of a child's life spent in daycare adjusting for age, including those children that never attended daycare (Table 15), do not reach statistical significance (p=0.108). When the sample is restricted to children that ever attended daycare, number of months children spent in daycare has even less effect (p=0.219). The age when children began daycare is not statistically significant, but asthmatic children started daycare at slightly earlier ages than non-asthmatic children. As the issue is what increases the risk of asthma, children diagnosed with asthma before beginning daycare are counted in analyses as never having attended daycare.

There was no difference in asthma rates by number of people or number of

children (defined as less than or equal to sixteen years old) in the households into which children were born or by number of people in the household at the T3 follow-up interview (Table 16). At T3, twelve percent fewer children lived in the household of asthmatic children (p=0.142). Number of people per square foot of living space does not associate with asthma.

Table 14.

WHETHER CHILD HAS EVER ATTENDED GROUP DAYCARE			Percent with Asthma	χ^2 p-value
ALL CHILDREN	N=50	Never in daycare	20.00	
	N=74	Attended daycare	28.38	0.291

Table 15.

CHILD'S DAYCARE HISTORY			Mean	Std. Dev.	T-test p-value
T3 TOTAL MONTHS CHILD HAS SPENT IN DAYCARE, INCLUDING CHILDREN THAT NEVER ATTENDED, RESIDUALS ADJUSTING FOR CHILD'S AGE					
ALL CHILDREN	N=93	Child not asthmatic	-0.9771	14.2660	
	N=30	Child asthmatic	2.9312	17.5265	0.108
T3 TOTAL MONTHS CHILD HAS SPENT IN DAYCARE, IF EVER ATTENDED, RESIDUALS ADJUSTING FOR CHILD'S AGE					
ALL CHILDREN	N=53	Child not asthmatic	-0.8563	13.9885	
	N=24	Child asthmatic	2.1612	17.2809	0.219
AGE IN MONTHS WHEN CHILD FIRST BEGAN ATTENDING DAYCARE, IF EVER ATTENDED					
ALL CHILDREN	N=51	Child not asthmatic	23.59	20.07	
	N=21	Child asthmatic	20.24	17.16	0.253

Table 16.

HOUSEHOLD SIZE			Mean	Std. Dev.	T-test p-value
T1 TOTAL PEOPLE IN HOUSEHOLD					
ALL CHILDREN	**N=98**	**Child not asthmatic**	3.71	1.84	
	N=30	**Child asthmatic**	3.53	1.53	0.313
T1 TOTAL CHILDREN IN HOUSEHOLD					
ALL CHILDREN	**N=100**	**Child not asthmatic**	1.22	1.21	
	N=31	**Child asthmatic**	1.23	1.12	0.490
T3 TOTAL PEOPLE IN HOUSEHOLD					
ALL CHILDREN	**N=100**	**Child not asthmatic**	4.82	1.59	
	N=29	**Child asthmatic**	4.66	1.54	0.310
T3 TOTAL CHILDREN IN HOUSEHOLD					
ALL CHILDREN	**N=100**	**Child not asthmatic**	2.94	1.46	
	N=29	**Child asthmatic**	2.62	1.18	0.142
T3 TOTAL PEOPLE IN HOUSEHOLD PER SQUARE FOOTAGE					
ALL CHILDREN	**N=94**	**Child not asthmatic**	0.0056	0.0020	
	N=29	**Child asthmatic**	0.0054	0.0024	0.320

Hypothesis 5—A mother's pregnancy history will predict asthma in children.

Hypothesis 5a—children born to mothers of higher parity will be less likely to have asthma

Hypothesis 5b—children born to mothers who have had elective abortions will be more likely to have asthma.

ANALYSES

Whether or not a child has an older sibling is not associated with asthma (Table 17), but children with asthma have fewer older siblings by their mother than other children (Table 18). The negative association between a child's birth rank and asthma is significant in the OU MCH sample ($p=0.036$). The number of pregnancies the mother had up to and including the index child is not significant.

Distinguishing pregnancies that did not result in a live birth from those that did produce a significant pattern. More previous pregnancies that did not result in a live birth increase the risk of asthma in a subsequent child (Table 19) while a history of successful pregnancies reduces risk (Table 18). Further separation of spontaneous from elective abortions demonstrates that only elective abortions pose significant risk of asthma in later children (Table 19). Fifty percent of children whose mothers had at least one elective abortion developed asthma, a relative risk of 2.65 over children whose mothers never had an elective abortion ($p=0.003$).

Because the decision to have an elective abortion is made within a social context that is often difficult, the influence of elective abortion is analyzed relative to the potential confounders of ethnicity, marital status, income, and education level (Tables 20 and 21). Elective abortions associate strongly with asthma in later children among both European-Americans and African-Americans (Table 20). The

relative risk of elective abortion is 2.94 for European-Americans (p=0.039) and 2.67 for African-Americans (p=0.035). History of elective abortion in T1 single mothers associates with asthma (relative risk 2.96, p=0.002). Only seven women married while pregnant with the index child had ever had an elective abortion; of those, one index child later developed asthma. Asthma in index children associates with residuals of prior elective abortions adjusting for T1 household income (p=0.016) and residuals of elective abortions adjusting for mother's T1 education level (p=0.019), (Table 21).

To separate further the issues of number of people in the house from number of children born to mothers, regression residuals are created taking the effect of household size out of parity (Table 22). Asthmatic children were born to mothers of lower parity, but the relationship falls short of significance (p=0.063). Looking at children not born first (Table 22, lower part) shows the protective effect of higher maternal parity is stronger (p=0.029).

Residuals of household size adjusted for the effect of mother's parity do not associate significantly with asthma in children (Table 23). Number of children in households at T3 adjusted for parity similarly does not associate with asthma.

Table 17.

WHETHER OR NOT INDEX CHILD HAS AN OLDER MATERNAL SIBLING			Percent with Asthma	χ^2 p-value
ALL CHILDREN	N=42	No older siblings	23.81	
	N=89	Older siblings	23.60	0.979

Table 18.

MOTHER'S PARITY			Mean	Std. Dev.	T-test p-value
BIRTH RANK OF INDEX CHILD					
ALL CHILDREN	N=100	Child not asthmatic	2.40	1.36	
	N=31	Child asthmatic	2.03	0.95	0.047
CHILD'S PREGNANCY RANK					
ALL CHILDREN	N=96	Child not asthmatic	2.84	1.58	
	N=30	Child asthmatic	2.87	1.53	0.472

Table 19.

MOTHER'S HISTORY OF PREGNANCIES NOT RESULTING IN A LIVE BIRTH			Percent with Asthma	χ^2 p-value
WHETHER OR NOT MOTHER HAS HISTORY OF LOST PREGNANCY BEFOR INDEX CHILD				
ALL MOTHERS	N=85	No pregnancy loss	17.50	
	N=46	Pregnancy loss	34.78	0.028
HISTORY OF ONE OR MORE SPONTANEOUS MISCARRIAGES (INCLUDING ECTOPIC PREGNANCIES AND STILLBIRTHS)				
ALL MOTHERS	N=94	No miscarriages	21.28	
	N=31	Miscarriage	29.03	0.375
HISTORY OF ONE OR MORE ELECTIVE ABORTIONS				
ALL MOTHERS	N=106	No elective abortion	18.87	
	N=20	Elective abortion	50.00	0.003

Table 20.

MOTHER'S HISTORY OF ELECTIVE ABORTION BY ETHNICITY AND MARITAL STATUS			Percent with Asthma	χ^2 p-value
EUROPEAN-AMERICANS	N=53	No elective abortion	15.09	
	N=9	Elective abortion	44.44	0.039
AFRICAN-AMERICANS	N=48	No elective abortion	25.00	
	N=6	Elective abortion	66.67	0.035
T1 SINGLE	N=62	No elective abortion	22.56	
	N=12	Elective abortion	66.67	0.002
T1 MARRIED	N=42	No elective abortion	14.29	
	N=7	Elective abortion	14.29	1.000

Table 21.

MOTHER'S HISTORY OF ELECTIVE ABORTION ADJUSTED FOR INCOME AND EDUCATION			Mean	Std. Dev.	T-test p-value
NUMBER OF ELECTIVE ABORTIONS ADJUSTED FOR T1 HOUSEHOLD INCOME					
ALL MOTHERS	N=78	Child not asthmatic	-0.0553	0.3047	
	N=23	Child asthmatic	0.1874	0.4883	0.016
NUMBER OF ELECTIVE ABORTIONS ADJUSTED FOR T1 MOTHER'S YEARS OF EDUCATION					
ALL MOTHERS	N=94	Child not asthmatic	-0.0474	0.3093	
	N=29	Child asthmatic	0.1535	0.4722	0.019

Table 22.

MOTHER'S PARITY ADJUSTING FOR NUMBER OF PEOPLE IN HOUSEHOLD			Mean	Std. Dev.	T-test p-value
PARITY RESIDUALS AFTER ADJUSTING FOR T1 NUMBER OF PEOPLE IN HOUSEHOLD					
ALL MOTHERS	**N=98**	**Child not asthmatic**	0.078	1.278	
	N=30	**Child asthmatic**	-0.255	0.942	0.063
PARITY RESIDUALS AFTER ADJUSTING FOR T1 NUMBER OF PEOPLE IN HOUSEHOLD FOR WOMEN WITH AT LEAST ONE PREVIOUS CHILD (INDEX CHILD AT LEAST SECOND BORN)					
ALL MOTHERS	**N=67**	**Child not asthmatic**	0.688	1.041	
	N=20	**Child asthmatic**	0.200	0.813	0.029

Table 23.

HOUSEHOLD SIZE ADJUSTING FOR PARITY OF MOTHER			Mean	Std. Dev.	T-test p-value
T1 NUMBER OF PEOPLE IN HOUSEHOLD RESIDUALS AFTER ADJUSTING FOR PREVIOUS CHILDREN BORN TO MOTHER					
ALL HOUSEHOLDS	**N=98**	**Child not asthmatic**	0.004	1.737	
	N=30	**Child asthmatic**	-0.012	1.479	0.482
T3 NUMBER OF CHILDREN IN HOUSEHOLD RESIDUALS AFTER ADJUSTING FOR PREVIOUS CHILDREN BORN TO MOTHER					
ALL HOUSEHOLDS	**N=100**	**Child not asthmatic**	0.026	1.233	
	N=29	**Child asthmatic**	-0.091	1.001	0.320

Hypothesis 6—Asthmatic children will have younger mothers.

ANALYSIS

Mothers of children with asthma were more than two years younger when they gave birth than were mothers of children not diagnosed with asthma (Table 24; p=0.009).

Maternal age residuals adjusting for history of elective abortions and previous live births (Table 25) remain significant (p=0.048). Residuals taking the effect of maternal age out of number of elective abortions remain strongly associated with asthma in index children (p=0.006).

Table 24.

T2 AGE OF MOTHER AT TIME OF CHILD'S BIRTH			Mean	Std. Dev.	T-test p-value
ALL MOTHERS	N=100	Child not asthmatic	25.61	5.22	
	N=31	Child asthmatic	23.18	4.02	0.009

Table 25.

MOTHER'S AGE VERSUS REPRODUCTIVE HISTORY			Mean	Std. Dev.	T-test p-value
AGE OF MOTHER RESIDUALS ADJUSTING FOR ELECTIVE ABORTIONS AND CHILD'S BIRTH RANK					
ALL MOTHERS	**N=96**	**Child not asthmatic**	0.34	4.24	
	N=30	**Child asthmatic**	-1.09	3.41	0.048
CHILD'S BIRTH RANK RESIDUALS ADJUSTING FOR AGE OF MOTHER					
ALL MOTHERS	**N=100**	**Child not asthmatic**	0.01	1.11	
	N=31	**Child asthmatic**	-0.02	0.79	0.452
ELECTIVE ABORTIONS RESIDUALS ADJUSTING FOR AGE OF MOTHER					
ALL MOTHERS	**N=96**	**Child not asthmatic**	-0.07	0.31	
	N=30	**Child asthmatic**	0.21	0.55	0.006

DISCUSSION OF HYPOTHESES 4, 5, AND 6

Previous researchers interested in the hygiene hypothesis have claimed that children of higher birth rank have less risk of asthma, because their older siblings expose them to more viruses (Ball et al., 2000; Bodner, Godden, andSeaton, 1998; Braback and Hedberg, 1998; Infante-Rivard, 1993; Lewis and Britton, 1998; von Mutius et al., 1994b; Ponsonby et al., 1998; Rona, Duran-Tauleria, and Chinn, 1997; Svanes et al., 1999). Similarly, a claim is made that daycare is protective because of exposure to children and viruses (Ball et al., 2000). The logic is that early viral infections protect from later allergy by priming the infant's developing immune system. Studies considering siblings as protective have presented information only on number of siblings in the household or total people in the household, so the possible confounder of how many times the mother has been pregnant has not been addressed.

One cross-sectional survey of 1447 children in Norway finds increased risk of early infections with daycare and increased risk of asthma with early infections (Nystad, Skrondal, and Magnus, 1999). The direct effect of daycare attendance on asthma is not large, OR = 1.2, but is in the direction of daycare being a risk rather than protective for asthma. Similarly, the OU MCH children were somewhat more likely to have been diagnosed with asthma if they had attended daycare. The relationship is not statistically significant. The number of months a child attended daycare had little affect on asthma either. The children with asthma that attended daycare started 3.4 months earlier than children that attended daycare but did not

develop asthma. Daycare attendance had little affect on the OU MCH children's risk of asthma, but the trend is for daycare to be a risk factor rather than protective. The pattern in the OU MCH data is not necessarily incompatible with the findings of Ball et al. (2000) from the Tucson Children's Respiratory Study. They report a protective effect for daycare, but only for children that attended daycare during the first six months of life. The Tucson children that attended daycare early in their lives wheezed more at age two but less from the ages of six to thirteen years.

Other studies have noted that children with younger mothers are more likely to develop asthma (Ball et al., 2000; Martinez, 1997b; Martinez et al., 1992). But younger mothers would also have fewer children, so the relative importance of number of siblings and maternal age needs to be teased out.

Analyses presented here suggest that, for a child's risk of asthma, the mother's history of prior pregnancies and her age exert more influence than number of people living in the home. Number of total people or number of children living in the household the child was born into had no effect on later asthma. Neither were asthma rates influenced by number of people in the household at follow-up or people per square-footage of living space at follow-up.

These observations prompt a look at total number of pregnancies, including both those that did not result in a live birth as well as those that did. Average total number of mother's pregnancies do not differ by whether the child had asthma. Separating pregnancies that resulted in live birth from those that did not shows that a history of one or more failed pregnancies (miscarriages or elective abortions) doubles

the risk of asthma in a subsequent child (17.6 versus 34.8 percent, p=0.028). The more miscarriages or abortions a woman has had, the more likely her child is to develop asthma. Thus maternal history of prior successful pregnancies is protective while history of lost pregnancies is deleterious for asthma in a subsequent child.

Pregnancies that did not result in a live birth are further divided into spontaneous miscarriages (this category includes a few ectopic pregnancies and stillbirths) and elective abortions. A mother's history of prior miscarriages associates only weakly with higher risk of asthma in a child. Prior elective abortions are strongly associated with asthma in a later child. Children whose mothers reported they had ever had an elective abortion were 2.6 times (50.0 versus 18.9 percent) more likely to have asthma (p=0.003). The relationship between prior maternal abortions and asthma holds up in a created residual variable reflecting abortions with the effect of household income adjusted. The same is true for residuals taking out the effects of mothers' education and age. Separated by prenatal marital status, children of married women had no different risk of asthma depending on whether their mother had ever had an elective abortion. However, only seven women that were married during their pregnancies had ever had an elective abortion. Among single mothers, prior elective abortion still doubles the risk of later asthma in the index child (p=0.002). There is no difference in rates of asthma among mothers themselves by whether they had ever terminated a pregnancy. Similarly, previous maternal elective abortion is strongly associated with asthma in children regardless of whether their mothers had asthma. The main limitation of these analyses is the small number of women that reported an

elective abortion. Only twenty of the 131 mothers had ever had an abortion. The magnitude of the effect and statistical significance of abortion holds up, though, in controlling for potential confounders.

Mothers of children with asthma averaged 2.4 years younger than other mothers at the time of their child's birth ($p=0.009$). After controlling for mother's age, the child's birth rank no longer associates with asthma. Residuals of mother's age controlling for the child's birth rank still associate with asthma. Mother's age associates with asthma after adjusting for number of people living in the household the child was born into. Number of people in the household is not associated with asthma after adjusting for maternal age. Clearly, age of mothers is a bigger issue than number of children born to her or number of people living in the household. However, previous elective abortion still confers risk regardless of the mother's age. Number of people in the household exerts little effect on asthma in children, on its own or after adjustment for pregnancy history or maternal age.

Older mothers may have less Th2-dominance in their pregnancies. A study comparing immune function by age finds more Th1 committed cells in older people (Sakata-Kaneko et al., 2000). These researchers compared young to old people. This study, therefore, does not fully establish a gradual and continuous shift from Th2 to Th1 dominance throughout the adult lifespan. However, it is logical that such a gradual change may occur and the effect may be great enough to influence risk of asthma in children born to mothers of different ages.

The next issue to explore is why elective abortions might confer greater risk for asthma in a subsequent child. There might be sociocultural differences in women who have had abortions that increase their awareness of health issues and anxiety about symptoms in subsequent children. If so, the difference could be one of likelihood for diagnosis rather than a physiological difference in children whose mothers have terminated a previous pregnancy. An immunological difference in children born to mothers with a history of elective abortion is also possible. Current scientific understanding does not fill in all the pieces for a full explanation, but there are several points worth considering.

Successful pregnancy requires trade-off between the needs of the mother and the needs of the fetus. For example, a smaller baby with a smaller head is easier and safer for a mother to deliver. But a larger baby is more robust and has a better chance of survival after birth. So natural selection has struck a delicate balance in the rate of fetal growth and timing of parturition to maximize the chances a child will be born healthy and the mother will also survive. The system is imperfect. Some babies are born too soon or too small for viability; and, throughout most of human history, many women died in childbirth.

A comparable give and take occurs in a woman's immune system. A balance between Th1 and Th2 type cytokines is best for protecting people from a variety of antigens, and an imbalance with cytokines associated with either Th1 or Th2 dominating can cause autoimmune disease. But a fetus and its placenta are foreign invaders in a woman's body. The mother's immune system recognizes the fetus,

which carries genetic information from its father as well as its mother, as separate from herself. Th1-type immune function kills infected or foreign cells, so strong Th1 can destroy a placenta and fetus. A healthy pregnancy requires the mother's immune function to be shifted toward Th2-type function and promotes especially IL-4, a cytokine closely associated with allergy and asthma (Formby, 1995; Matthiesen et al., 1998; Piccinni, Maggi, and Romagnani, 2000; Weetman, 1999). Predominance of Th1 is associated with recurrent miscarriage (Hill and Choi, 2000; Jenkins et al., 2000; Raghupathy et al., 1999).

It is logical, then, that history of spontaneous miscarriages in mothers would not be associated with asthma in children. Miscarriages tend to be associated with the type of immunological climate less likely to lead to allergy and asthma. But what happens after an elective abortion? After a normal pregnancy and delivery, there is a resolution phase during which the mother's immune function returns to a more equitable balance between Th1 and Th2 activity as levels of Th2-type cytokines subside (Matthiesen et al., 1998; Omu et al., 1999; Wilder, 1998). Otherwise, given that pregnancy is strongly Th2-dominant, women would all fall prey to Th2-type autoimmune diseases plus loose their ability to fight many infectious diseases (Wilder, 1998). Abrupt termination of a normally progressing—and therefore Th2 dominated—pregnancy may cut short the processes or signals that insure a return to immunological balance.

Another possibility is that a woman's body may compensate for each failed pregnancy by tipping further toward Th2-type immunological functioning in order to

increase chances of successful pregnancy in the future. As many spontaneous abortions occur in a Th1-dominant immune climate, higher levels of Th2 cells in successive pregnancies following a failed one would be adaptive and increase chances of reproductive success. The body may be unable to distinguish a pathological spontaneously aborted pregnancy from an immunologically normal pregnancy terminated surgically. The result would be an inappropriate immunological compensation toward more Th2 function following elective abortion.

The OU MCH data provide indirect evidence of compensation during pregnancy associated with an earlier abortion. Women that had ever terminated a previous pregnancy produced placentas averaging 132 grams or 22 percent larger in their pregnancy with the index child ($p=0.012$). Placentas were slightly (31 grams) and non-significantly ($p=0.293$) smaller for women with history of a previous spontaneous miscarriage. Placental weight has been associated with parity in other studies (Hindmarsh et al., 2000), but the two do not associate in the OU MCH data. Women with a history of elective abortion averaged a scant 9 percent higher pre-pregnancy body mass relative to ideal ($p=0.218$), but previous abortion does not associate with body mass of mothers at follow-up or, consequently, their weight gain from pre-pregnancy to follow-up.

Infants born to mothers with a history of elective abortion had head circumferences 2.2 percent larger than children whose mothers had never terminated a pregnancy ($p=0.024$). Larger head circumference at birth has been associated with higher IgE levels and risk of asthma in childhood (Fergusson et al., 1997; Gregory et

al., 1999; Leadbitter et al., 1999). What larger head circumference represents in relation to IgE or atopy has never been established. The connection may be maternal reproductive history. Birth weight adjusted for gestational age was also higher in infants of mothers with a history of a terminated pregnancy. Infants of mothers with previous abortions had birth weight residuals on average 159 grams above the regression line whereas other infants' residuals averaged 31 grams below the regression line ($p=0.058$). Taken together, larger placentas, larger head circumferences at birth, and higher birth weight for gestational age suggest more rapid growth in fetuses of women that have had previous abortions.

No other studies have looked at prior births, miscarriages, or abortions in relation to risk of asthma in children. One study does conclude that greater number of siblings is protective and that it does not matter whether they are older or younger siblings (Mattes, et al., 1999). Type I diabetes, thought to be a Th1-dominated autoimmune disease (Cameron et al., 1997; DeCarli et al., 1994; Karlsson, Lawesson, and Ludvigsson, 2000), associates in children with higher birth order and more prior pregnancies, lumping miscarriages along with elective abortions (Tai et al., 1998).

Nationwide, rates of elective abortion fit the demographic profile of groups with highest asthma risk among children (CDC, 1999). Abortion is most common among young, less affluent, unmarried women. Although more abortions are performed on European-American women, abortion rates are higher for African-Americans.

To further distinguish a maternal parity and age related effect during pregnancy from exposure to other children in the home, future studies could examine children living in household with other children that are not their maternal siblings. Influence of paternal half siblings could be studied. The simplest method would be to study adopted children with known parity of biological mother.

In sum, analyses of the OU MCH data suggest age and reproductive history of mothers are more important than exposure to people—through number of people living with a child or daycare—for risk of asthma. Greater parity is protective but, in these data, the effect of parity does not hold up after controlling for maternal age. Although previous spontaneous miscarriage in mothers does not alter risk of asthma in a child, an early elective abortion substantially increases the chances a later child will develop asthma.

Maternal Obesity

Hypothesis 7—Asthma will be more prevalent in children of mothers with higher body mass.

ANALYSIS

The reference standard for mothers' weight-for-height has been obtained from the formula: weight in kilograms / (0.53 x height in centimeters) – 25.55, derived from the regression equation of weight and height of women in the age group 18 to 24 in the United States according to the Health and Nutritional Examination Survey (DHEW, 1979; Gueri, Jutsum, and Sorhaindo, 1982). "Ideal" means the lowest mortality rates for height in the United States. Several methods are commonly used in the literature for assessing body mass. Body mass and ponderal indexes are both common. The goal is to find a formula that adjusts for height such that weight no longer associates statistically with height. The method used here was chosen for this study empirically as it most effectively removes the effect of height from weight in the OUHSC NIHP sample. A score of 100 indicates the woman's weight is ideal for her height and best health. A score less than 100 indicates she is thinner than ideal, and a score more than 100 indicates she is heavier than would be best for her health. For example, a score of 120 means the woman weighs 20 percent more than optimum. Weight scores are calculated both for the weight of each mother before she became pregnant and at her follow-up interview.

Maternal pre-pregnancy (T1) weight for height is slightly (5 percent) higher for asthmatic children (Table 26) but not statistically significant. Mothers' weight at follow-up (T3) associates strongly with asthma in children (Table 26). Mothers of asthmatic children weighed 12 percent more than mothers of children without asthma ($p=0.024$). The association is not statistically significant in African-Americans but highly significant in European-American children. Among European-Americans, mothers of asthmatic children weighed 25 percent more than mothers of children without asthma ($p=0.003$).

The strongest relationship between maternal size and asthma is in the amount of weight mothers gained since their pregnancy (Table 26). Mothers of children with asthma gained nearly 80 percent more weight than mothers of non-asthmatic children ($p=0.005$). Among European-Americans, mothers of asthmatic children gained more than three times more weight since their pregnancies ($p=0.0004$). Maternal weight gain does not reach statistical significance among African-Americans.

Because smoking influences body mass, analyses are repeated for mothers who did not smoke during their pregnancies (Table 27) and those that did smoke (Table 28). The trend of mothers of asthmatic children being heavier remains among the group whose mothers did not smoke. Among smokers, mother of asthmatic children had higher body mass at follow-up and more weight gain since their pregnancy. Only one African-American mother smoked prenatally, so no estimate can be made of the effect of obesity among smoking African-American mothers.

All circumference and skinfold anthropometric measurements indicative of fatness in mothers at follow-up (T3) have a positive association with asthma in children and reach statistical significance. Results of T3 body fat anthropometric measurements of mothers are summarized in Table 29.

Table 26.

T1 & T3 MOTHER'S ANTHROPOMETRIC MEASUREMENTS			Mean	Std. Dev.	T-test p-value
T1 MOTHER'S PRE-PREGNANCY BODY MASS AS PERCENT OF IDEAL FOR HEIGHT					
ALL MOTHERS	**N=94**	**Child not asthmatic**	107.96	28.62	
	N=29	**Child asthmatic**	113.27	32.09	0.198
EUROPEAN-AMERICANS	**N=48**	**Child not asthmatic**	104.85	26.55	
	N=13	**Child asthmatic**	108.70	32.46	0.330
AFRICAN-AMERICANS	**N=37**	**Child not asthmatic**	109.58	32.06	
	N=14	**Child asthmatic**	112.53	29.64	0.383
T3 MOTHER'S BODY MASS AS PERCENT OF IDEAL FOR HEIGHT					
ALL MOTHERS	**N=100**	**Child not asthmatic**	124.26	36.79	
	N=31	**Child asthmatic**	139.07	33.81	0.024
EUROPEAN-AMERICANS	**N=50**	**Child not asthmatic**	115.53	30.68	
	N=13	**Child asthmatic**	144.42	39.32	0.003
AFRICAN-AMERICANS	**N=41**	**Child not asthmatic**	131.03	42.30	
	N=16	**Child asthmatic**	135.28	31.05	0.358
MOTHER'S WEIGHT GAIN FROM T1 PREPREGNANCY TO T3 IN KILOGRAMS					
ALL MOTHERS	**N=94**	**Child not asthmatic**	9.37	13.09	
	N=29	**Child asthmatic**	16.82	14.14	0.005
EUROPEAN-AMERICANS	**N=48**	**Child not asthmatic**	6.51	13.53	
	N=13	**Child asthmatic**	21.82	15.18	0.0004
AFRICAN-AMERICANS	**N=37**	**Child not asthmatic**	11.97	12.69	
	N=14	**Child asthmatic**	15.85	8.74	0.147

Table 27.

T1 & T3 MOTHER'S ANTHROPOMETRIC MEASUREMENTS, DID NOT SMOKE T1			Mean	Std. Dev.	T-test p-value
T1 MOTHER'S PRE-PREGNANCY BODY MASS AS PERCENT OF IDEAL FOR HEIGHT					
ALL MOTHERS	**N=51**	**Child not asthmatic**	111.08	29.00	
	N=20	**Child asthmatic**	118.91	33.34	0.165
EUROPEAN-AMERICANS	**N=21**	**Child not asthmatic**	110.52	21.98	
	N=5	**Child asthmatic**	124.52	36.06	0.135
AFRICAN-AMERICANS	**N=25**	**Child not asthmatic**	110.48	35.30	
	N=14	**Child asthmatic**	112.53	29.64	0.428
T3 MOTHER'S BODY MASS AS PERCENT OF IDEAL FOR HEIGHT					
ALL MOTHERS	**N=55**	**Child not asthmatic**	132.43	37.73	
	N=20	**Child asthmatic**	147.38	36.23	0.065
EUROPEAN-AMERICANS	**N=22**	**Child not asthmatic**	128.22	30.36	
	N=5	**Child asthmatic**	172.02	42.82	0.006
AFRICAN-AMERICANS	**N=28**	**Child not asthmatic**	133.76	44.55	
	N=14	**Child asthmatic**	138.23	32.08	0.370
MOTHER'S WEIGHT GAIN FROM T1 PREPREGNANCY TO T3 IN KILOGRAMS					
ALL MOTHERS	**N=51**	**Child not asthmatic**	21.15	18.87	
	N=20	**Child asthmatic**	28.47	25.03	0.093
EUROPEAN-AMERICANS	**N=21**	**Child not asthmatic**	16.81	16.84	
	N=5	**Child asthmatic**	47.49	33.09	0.054
AFRICAN-AMERICANS	**N=25**	**Child not asthmatic**	23.63	20.41	
	N=14	**Child asthmatic**	25.71	13.68	0.368

Table 28.

T1 & T3 MOTHER'S ANTHROPOMETRIC MEASUREMENTS, SMOKED T1			Mean	Std. Dev.	T-test p-value
T1 MOTHER'S PRE-PREGNANCY BODY MASS AS PERCENT OF IDEAL FOR HEIGHT					
ALL MOTHERS	**N=43**	**Child not asthmatic**	104.22	28.05	
	N=9	**Child asthmatic**	100.73	26.63	0.367
EUROPEAN-AMERICANS	**N=27**	**Child not asthmatic**	100.44	29.27	
	N=8	**Child asthmatic**	98.81	27.79	0.445
AFRICAN-AMERICANS	**N=12**	**Child not asthmatic**	0.011	0.253	
	N=0	**Child asthmatic**	N/A	N/A	N/A
T3 MOTHER'S BODY MASS AS PERCENT OF IDEAL FOR HEIGHT					
ALL MOTHERS	**N=43**	**Child not asthmatic**	112.81	30.34	
	N=10	**Child asthmatic**	124.15	24.58	0.139
EUROPEAN-AMERICANS	**N=27**	**Child not asthmatic**	106.46	27.63	
	N=8	**Child asthmatic**	127.17	26.80	0.035
AFRICAN-AMERICANS	**N=12**	**Child not asthmatic**	118.09	0.295	
	N=1	**Child asthmatic**	107.38	--	0.367
MOTHER'S WEIGHT GAIN FROM T1 PREPREGNANCY TO T3 IN KILOGRAMS					
ALL MOTHERS	**N=43**	**Child not asthmatic**	8.59	24.14	
	N=9	**Child asthmatic**	25.28	19.05	0.029
EUROPEAN-AMERICANS	**N=27**	**Child not asthmatic**	6.02	27.36	
	N=8	**Child asthmatic**	28.36	17.81	0.019
AFRICAN-AMERICANS	**N=12**	**Child not asthmatic**	0.104	0.179	
	N=0	**Child asthmatic**	N/A	N/A	N/A

Table 29.

T3 MOTHER'S SOFT TISSUE ANTHROPOMETRIC MEASUREMENTS		Mean	Std. Dev.	T-test p-value
Forearm circumference (cm)	Child not asthmatic	25.50	2.73	
	Child asthmatic	26.95	2.66	0.007
Biceps circumference (cm)	Child not asthmatic	31.11	5.83	
	Child asthmatic	33.73	4.84	0.015
Wrist circumference above widest bump of radius (cm)	Child not asthmatic	16.24	1.73	
	Child asthmatic	16.96	1.70	0.028
Thigh circumference at halt-way point (cm)	Child not asthmatic	55.36	8.99	
	Child asthmatic	59.63	9.41	0.014
Thigh circumference just below gluteal fold (cm)	Child not asthmatic	62.80	9.60	
	Child asthmatic	66.69	8.10	0.017
Chest circumference under breasts at exhale (cm)	Child not asthmatic	88.73	12.73	
	Child asthmatic	93.65	12.59	0.036
Waist circumference one inch above naval (cm)	Child not asthmatic	88.37	16.63	
	Child asthmatic	95.16	20.77	0.036
Hip circumference at iliac crest (cm)	Child not asthmatic	106.49	16.43	
	Child asthmatic	114.67	17.81	0.012
Biceps skinfold at half-way point of upper arm (mm)	Child not asthmatic	16.22	8.70	
	Child asthmatic	23.26	13.22	0.005
Triceps skinfold at half-way point of upper arm (mm)	Child not asthmatic	22.58	10.75	
	Child asthmatic	27.19	9.86	0.021
Subscapular skinfold (mm)	Child not asthmatic	24.07	10.86	
	Child asthmatic	30.10	11.45	0.005
Forearm skinfold 1.5 inches below elbow joint (mm)	Child not asthmatic	11.62	5.94	
	Child asthmatic	14.52	7.22	0.018
Thigh skinfold in front at high-way point (mm)	Child not asthmatic	33.44	12.42	
	Child asthmatic	39.76	13.81	0.011

DISCUSSION

Children whose mothers were overweight were more likely to have asthma, even if the children were not overweight themselves. Previous studies have linked asthma to obesity in women and in older children. Published studies have not looked at the relationship between obesity and asthma in children younger than nine years. Analyses on the four- to seven-year-old OU MCH children show the risk for young children is obesity in their mothers.

That higher body mass in one generation corresponds to higher risk of asthma in the next helps clarify some issues. Until recently, most researchers and clinicians assumed that people with asthma are often heavy because they cannot be as active and, therefore, burn fewer calories. Camargo et al.'s (1999) longitudinal research shows that obese people are more likely to develop asthma. That is, obesity often comes before asthma. Perhaps, some now speculate, excess abdominal fat restricts the diaphragm and airways, causing reduced lung function and a corresponding predisposition to asthma. Alternatively, less active people may breathe more shallowly. These mechanical explanations are not adequate to explain how risk of asthma can be higher for children that are not overweight but have heavy mothers.

Pre-pregnancy weight of mothers does not associate with later asthma in their children. Only weight of mothers at follow-up (T3), and particularly their weight gain since pregnancy, associates with asthma in children. It is worth noting that Camargo et al.'s (1999) study of obesity and asthma risk in women found highest association of the disease with weight gained since age eighteen. As the association

in the OU MCH study is with body mass of mothers well after their pregnancies, obesity in mothers could not directly cause asthma in their children. If the association is not from chance, the link must be either in the lifestyle mothers and children share or a biological difference during pregnancy that leads later to both obesity in mothers and asthma in children. Both possibilities are explored below.

(1) Obesity in mothers could be a surrogate for the habits the mother and child share after birth. Something other than maternal obesity itself, possibly diet or lack of exercise, could be the source of risk in children. No data on diet are available in the OU MCH study. The literature review in Chapter 2 addresses studies of diet and asthma. Hypotheses proffered relating asthma to diet tend to focus on specific nutritional elements rather than simply caloric intake. One exception is the Klein et al. (1991) study that found higher caloric intake among children with asthma. Studies of asthma and diet have not dealt with obesity. All the nutritional elements and deficiencies considered, though, are characteristics of modern dietary lifestyle associated with rapidly increasing prevalence of obesity.

Some researchers blame the sedentary modern lifestyle for rising rates of asthma. Platts-Mills (1997) has suggested that watching television keeps children from getting the exercise they need for their lungs to grow properly. Few studies have tested the effect of activity on asthma directly, and none have conclusively. The difficulty in designing a study of activity and asthma is the potential for selection bias. People with better initial lung function are apt to lead more active lives. It is not enough, for example, simply to contrast lung health of high school students that

participate in sports with those that do not. One elegantly controlled study in Quebec randomly assigned 546 first-grade students to regular or enhanced physical education classes. Half the children attended the standard 40-minute per week physical education course offered in Quebec schools. The intervention group was enrolled in a five-hour per week physical education program. This expanded program was also more intense, taught by professional trainers emphasizing aerobic exercise. The program lasted through the six years of the children's primary education. The researchers focused on growth effects, but lung function measurements were also taken. Lung function benefits were small (Shephard and Lavallee, 1996).

Mothers in the OU MCH study were asked about how much time their children spent playing outdoors. Children are more active when they play outdoors, and they are away from the indoor allergens associated with asthma. Body mass of mothers associates negatively with how much time mothers reported their children played outside ($r = -0.22$, $p=0.016$). Furthermore, how much children played outside associates directly with asthma ($p=0.016$). Camargo et al. (1999), however, controlled for self-reported activity levels when they found a strong association between body mass and risk of asthma onset in women from the Nurses' Health Study II. In the OU MCH interviews, mothers often said they kept children with asthma inside to keep them from overexerting or getting too hot. Thus, the ethnographic evidence suggests asthmatic children staying indoors more is an aftereffect of the disease rather than a cause. Still, mothers' comments about why they kept asthmatic children indoors more are anecdotal and questions on this issue

were not asked systematically, so lower activity levels and time spent indoors cannot be eliminated as causal for asthma in the OU MCH sample. Lower activity levels among children could be the link between their asthma and maternal obesity.

(2) Obesity in mothers and asthma in children might share a biological cause that can pass from mothers to children. Mothers' current body mass might reflect a physiological phenotype shared by mothers and children that can predispose to obesity or asthma or both. Some children that are not obese now may become obese later and already be manifesting an obesity-related disease.

One clue tying weight gain in mothers after pregnancy to a difference during pregnancy is placental weight. Placentas of the asthmatic children weighted 67 grams or 11 percent more than placentas of non-asthmatic children. Mothers' pre-pregnancy weight does not associate with placental weight ($r=0.07$, $p=0.443$). Mother's weight at follow-up (T3) associates better with placental weight ($r=0.15$, $p=0.101$). Placental weight associates best, though, with weight gained by the mother from before her pregnancy to the time of the follow-up interview ($r=0.19$, $p=0.042$). Weight gain is also the maternal anthropometric variable that associates best with asthma in children. Higher placental weight, more weight gained by mothers, and asthma in children all associate positively with each other despite the fact that higher maternal parity (discussed earlier as protective for asthma in children) has been associated in previous studies with larger placentas (Hindmarsh et al., 2000). It is hard to hypothesize a meaning for placental weight in relation to asthma, but the pattern in the OU MCH data does establish that something about mothers who gained weight later was already

different during their pregnancies. Placental weight is discussed again below in exploring the relationship between reproductive history of mothers and asthma in children.

Mothers that would later become obese might have an immune difference. Several studies are suggestive that obesity and immune function are interrelated. In a Chilean study of children with respiratory syncytial virus (RSV), obese children had worse clinical symptoms and took longer to recover (Rivera et al., 1999). Children with more severe course with RSV infection are more likely to develop asthma later, probably because it elicits a Th2-type response (Stannegard et al., 1997).

Certain cytokines, particularly IL-1, IL-6, and tumor necrosis factor (TNF), influence metabolism (Grimble, 1996) and enhance allergic response (Aebischer and Stadler, 1996). During infection, these cytokines reduce appetite by increasing leptin, which is why anorexia often goes along with acute infection. However, there are feedback mechanisms involving interaction between cytokines, the hypothalamo-pituitary-adrenal (HPA), and diet that serve to keep cytokines, metabolism, and appetite in balance (Grimble, 1996). It has been suggested that IL-6 (Mohamed-Ali et al., 1997; Visser et al., 1999) and TNF (Hanson et al., 2000), the same cytokines that cause anorexic symptoms during infection or helmithic infestation, are produced by fat cells. A recent letter proposed that the Th2-type activity of IL-6 produced by adipose tissue could be the mechanism linking obesity and asthma (Varner, 2000). As proposed, though, this theory requires adipose tissue to be in place prior to excess production of cytokines. So that theory could not explain the association between

asthma in children and obesity in mothers that developed after pregnancy in the OU MCH mother-child dyads. Perhaps somehow in the cycle linking HPA activity and immune function, certain cytokines stimulate appetite. The mother's immune function might influence the fetus in utero and thereby contribute to both later obesity in the mother and asthma in the child. The difficulty with this scenario is that in the OU MCH sample, body mass of mothers associates stronger with asthma in children than with asthma in the mothers themselves (asthmatic mothers had 8 percent higher body mass percent of ideal for height, $p=0.159$).

The link between obesity and asthma could be endocrine. Simple obesity is associated with higher estrogen and lower androgen levels in women (Heber, 1996) and men (Stanik et al., 1981). Higher estrogen and lower androgen levels are both independently linked to less Th1-type and more Th2-type cytokine production (Giltay et al., 2000; Huber, Kupperman, and Newell, 1999). Generally the belief in the literature is that adipose cells are themselves responsible for the altered hormonal profile of overweight people and endocrine levels do little to predispose for obesity. However, a pre-obesity hormonal difference great enough to influence the immune function might exist in some people. That is, some mothers that are not yet obese but will be in the future might already be predisposed to obesity in a way that influences the prenatal environment. Maternal estrogens are passed to infants at least temporarily. Perhaps higher maternal estrogens promote the development of a Th2 phenotype once the infant's T-cells begin to differentiate. Alternately, mothers with higher estrogen and lower androgen levels may have a more extreme immune shift

toward Th2-type activity during pregnancy than other women, the shift influencing the immune development of the fetus.

There might be a genetic link between obesity and asthma, so that they tend to be inherited in tandem without one being the cause of the other. Body mass appears to have a genetic component. A codominant inheritance pattern has been found for body mass in African-Americans and Nigerians (Colilla et al., 2000) and for waist-to-hip ratio in European-Americans (An et al., 2000). Only indirect evidence is available so far to link inheritance of propensity for higher body mass and asthma. Barr et al. (2000) found a linkage between a specific gene polymorphism (Arg16Gly) and asthma in sedentary women but not active women. A second polymorphism (Gln27Glu) associated with body mass index only in sedentary women. Body mass index of these women associated with whether they had asthma. So, though the evidence in this study is not direct, it is suggestive of a genetic link between body mass index and asthma. In that case, obesity and asthma may tend to coexist without obesity causing asthma. As the linkage was found only in sedentary women, the study brings up the possibility of gene-environment interactions between activity levels, body mass, and asthma. But obesity in the OU MCH data did not directly increase risk of asthma in mothers, making genetic linkage of asthma and obesity a less likely explanation.

A virus is a final possibility. Recent research raises the possibility that human adenovirus contributes to obesity (Dhurandhar et al., 2000; Dhurandhar et al., 1997).

How much this phenomenon explains increasing obesity rates has not been estimated. Hypothetically, such a virus could in some way influence the onset of asthma.

Association between obesity in mothers and asthma in children is strong among European-American mothers and children in the OU MCH sample but weak among African-American mothers and children (African-American mothers of asthmatic children are 3 percent further from ideal weight-for-height, p=0.358). Interestingly, a very large prospective cohort study looking at the health effects of obesity found risk associated with higher body mass is greater for European-Americans than for African-Americans (Calle et al., 1999).

Fetal and Child Growth

Hypothesis 8—Asthma will be more prevalent among children with lower birth weight. Disaggregating birth weight categories will produce stronger patterns:

Hypothesis 8a—Prevalence of asthma will be higher in children born at earlier gestational ages, regardless of birth weight.

Hypothesis 8b—Retardation of prenatal growth will increase the risk of asthma later, and the consequences of asymmetrical growth retardation will be greater than symmetrical growth retardation.

Hypothesis 8c—Asthmatic children will have had smaller chest circumferences and shorter trunk-to-leg ratios at birth.

ANALYSES

Analyses for Hypothesis 8 are summarized in Tables 30-34. The mean birth weight of asthmatic children (Table 30) is 232 grams lower than the mean for children without asthma ($p=0.019$). Birth weight of children with asthma is lower among European-Americans and African-Americans and both sexes, although these subgroups are not listed in a table. Gestational age is slightly lower in the asthmatic group, but the difference is less than a week and not statistically significant ($p=0.153$).

Birth weight residuals, adjusting for gestational age, assess growth rate independent of the timing of birth or the length of gestation (Table 30). Regression was used to determine the equation that would remove the effects of gestation from birth weight. The Appendix lists regression equations used to create residuals. Asthmatic children were smaller for gestation ($p=0.018$). Similarly, regression residuals of birth weight adjusted for length, representing fatness at birth, are smaller for asthmatic children ($p=0.010$).

Although asthmatic children were smaller at birth, their placentas were 11 percent larger (Table 30). Placental weight, however, is not statistically significant as a predictor of asthma in OU MCH children (p=0.099).

Specific birth anthropometric measurements, including lengths, circumferences, and skinfolds of the children with and without asthma, are analyzed in Table 31. Three birth parameters associate with asthma. Crown-rump length associates negatively with asthma (p=0.034). Leg length, measured as crown-heal minus crown-rump length, associates positively with asthma (p=0.017). Chest circumference is smaller for asthmatic children (p=0.020).

Because trunk-to-leg ratios often differ between European-Americans and African-Americans (Gasperino, 1996), the three specific measurements that associate with asthma (crown-rump length, leg length, and chest circumference) are listed separately by ethnicity (Table 32). Boys and girls might also be different at birth, so measurements are separated for the sexes. The trend of shorter crown-rump length, longer leg length, and smaller chest circumference at birth is the same for asthmatic children in all subgroups. The magnitude of the chest circumference difference between those with and without asthma is greater in European-Americans (1.26 centimeters) than African-Americans (p=0.036). Shorter crown-rump length with corresponding longer leg length is statistically significant for girls but not boys. Smaller chest circumference is statistically significant for boys but not girls.

Table 30.

T2 BIRTH PARAMETERS OF INFANTS			Mean	Std. Dev.	T-test p-value
BIRTHWEIGHT IN GRAMS					
ALL INFANTS	**N=100**	**Child not asthmatic**	3354.20	544.85	
	N=31	**Child asthmatic**	3122.61	505.82	0.019
GESTATIONAL AGE IN WEEKS					
ALL INFANTS	**N=100**	**Child not asthmatic**	39.14	1.49	
	N=31	**Child asthmatic**	38.81	1.83	0.153
BIRTHWEIGHT RESIDUALS ADJUSTING FOR GESTATIONAL AGE					
ALL INFANTS	**N=100**	**Child not asthmatic**	43.41	517.02	
	N=31	**Child asthmatic**	-139.95	379.11	0.018
BIRTHWEIGHT RESIDUALS ADJUSTING FOR LENGTH					
ALL INFANTS	**N=89**	**Child not asthmatic**	43.18	362.22	
	N=29	**Child asthmatic**	-132.52	298.45	0.010
LENGTH RESIDUALS ADJUSTING FOR GESTIONAL AGE					
ALL INFANTS	**N=89**	**Child not asthmatic**	0.0144	2.6652	
	N=29	**Child asthmatic**	-0.0442	2.3211	0.4580
SIZE OF PLACENTA IN GRAMS					
ALL INFANTS	**N=97**	**Child not asthmatic**	605.48	324.94	
	N=30	**Child asthmatic**	672.83	218.93	0.099

Table 31.

T2 INFANT'S ANTHROPOMETRIC MEASUREMENTS		Mean	Std. Dev.	T-test p-value
CROWN-HEAL LENGTH	Child not asthmatic	49.83	2.75	
	Child asthmatic	49.72	2.45	0.417
CROWN-RUMP LENGTH	Child not asthmatic	33.52	2.15	
	Child asthmatic	32.78	1.77	0.034
LEG LENGTH	Child not asthmatic	16.33	2.23	
	Child asthmatic	17.13	1.50	0.017
HEAD CIRCUMFERENCE	Child not asthmatic	34.39	1.53	
	Child asthmatic	33.99	1.41	0.106
UPPER ARM CIRCUMFERENCE	Child not asthmatic	10.85	1.15	
	Child asthmatic	10.87	1.09	0.468
CHEST CIRCUMFERENCE	Child not asthmatic	33.09	2.25	
	Child asthmatic	32.15	1.66	0.020
THIGH CIRCUMFERENCE	Child not asthmatic	14.96	1.60	
	Child asthmatic	14.85	1.89	0.383
BACK THIGH SKINFOLD, 15 SECONDS	Child not asthmatic	5.44	1.99	
	Child asthmatic	5.26	1.51	0.335
BACK THIGH SKINFOLD, 60 SECONDS	Child not asthmatic	4.88	1.90	
	Child asthmatic	4.83	1.55	0.456
INTERSCAPULAR SKINFOLD, 15 SECONDS	Child not asthmatic	3.55	1.07	
	Child asthmatic	3.59	1.00	0.437
INTERSCAPULAR SKINFOLD, 60 SECONDS	Child not asthmatic	3.16	1.00	
	Child asthmatic	3.23	0.92	0.372

Table 32.

T2 INFANT'S ANTHROPOMETRIC MEASUREMENTS		Mean	Std. Dev.	T-test p-value
EUROPEAN-AMERICANS				
CROWN-RUMP LENGTH	Child not asthmatic	33.81	2.17	
	Child asthmatic	32.97	1.67	0.101
LEG LENGTH	Child not asthmatic	16.10	2.53	
	Child asthmatic	17.02	1.33	0.044
CHEST CIRCUMFERENCE	Child not asthmatic	33.21	2.36	
	Child asthmatic	31.95	1.42	0.036
AFRICAN-AMERICANS				
CROWN-RUMP LENGTH	Child not asthmatic	32.95	2.28	
	Child asthmatic	32.53	1.98	0.273
LEG LENGTH	Child not asthmatic	16.22	1.69	
	Child asthmatic	17.05	1.70	0.072
CHEST CIRCUMFERENCE	Child not asthmatic	32.40	2.03	
	Child asthmatic	32.13	1.93	0.337
GIRLS				
CROWN-RUMP LENGTH	Child not asthmatic	33.24	2.04	
	Child asthmatic	32.28	1.36	0.048
LEG LENGTH	Child not asthmatic	16.23	2.36	
	Child asthmatic	17.51	1.40	0.009
CHEST CIRCUMFERENCE	Child not asthmatic	32.76	2.12	
	Child asthmatic	32.10	1.72	0.140
BOYS				
CROWN-RUMP LENGTH	Child not asthmatic	33.82	2.24	
	Child asthmatic	33.31	2.03	0.225
LEG LENGTH	Child not asthmatic	16.44	2.10	
	Child asthmatic	16.75	1.54	0.306
CHEST CIRCUMFERENCE	Child not asthmatic	33.43	2.36	
	Child asthmatic	32.20	1.66	0.019

Hypothesis 9—Asthmatic children will not differ significantly from other children in their current weight-for-height-for-age.

ANALYSES

In order to estimate the weight of the children that is independent of height and age, weight was regressed on these two potential confounders. The residuals—weight that is not linearly related to height or age—were used to compare the fatness of asthmatic and non-asthmatic children at the time of the follow-up assessment (Table 33). Although asthmatic children are slightly thinner in all groups, the difference between asthmatic and non-asthmatic children is small and not statistically significant.

None of the soft tissue measurements that indicate fatness (circumferences and skinfolds) associate with asthma in children (Table 34). Bony measurements (height, arm and leg lengths, and head circumference, not in a table) do not associate with asthma in children either.

Table 33.

T3 CHILD'S WEIGHT RESIDUALS ADJUSTING FOR AGE AND HEIGHT			Mean	Std. Dev.	T-test p-value
ALL CHILDREN	N=99	Child not asthmatic	0.9438	51.5559	
	N=31	Child asthmatic	-3.0142	11.9599	0.241

Table 34.

T3 CHILD'S SOFT TISSUE ANTHROPOMETRIC RESIDUALS ADJUSTING FOR AGE		Mean	Std. Dev.	T-test p-value
Forearm circumference (cm)	Child not asthmatic	-0.3365	1.4739	
	Child asthmatic	1.0992	8.0123	0.168
Biceps circumference (cm)	Child not asthmatic	-0.2011	2.7461	
	Child asthmatic	0.6504	5.3073	0.202
Wrist circumference above widest bump of radius (cm)	Child not asthmatic	-0.0143	1.3059	
	Child asthmatic	0.0467	1.3773	0.413
Thigh circumference at halt-way point (cm)	Child not asthmatic	0.1313	3.9173	
	Child asthmatic	-0.4202	5.2343	0.299
Thigh circumference just below gluteal fold (cm)	Child not asthmatic	0.0761	5.0205	
	Child asthmatic	-0.2464	6.8444	0.414
Chest circumference under nipples at exhale (cm)	Child not asthmatic	-0.1872	4.4826	
	Child asthmatic	0.6116	5.4147	0.209
Waist circumference one inch above naval (cm)	Child not asthmatic	-0.3229	7.0021	
	Child asthmatic	1.0548	8.6428	0.187
Hip circumference at iliac crest (cm)	Child not asthmatic	1.2595	60.0723	
	Child asthmatic	-4.1142	8.2576	0.196
Biceps skinfold at half-way point of upper arm (mm)	Child not asthmatic	-0.0289	3.2554	
	Child asthmatic	0.0943	5.8922	0.457
Triceps skinfold at half-way point of upper arm (mm)	Child not asthmatic	0.0106	4.2958	
	Child asthmatic	-0.0345	6.7657	0.486
Subscapular skinfold (mm)	Child not asthmatic	0.0254	3.8840	
	Child asthmatic	-0.0822	4.3511	0.449
Forearm skinfold 1.5 inches below elbow joint (mm)	Child not asthmatic	0.1493	3.0220	
	Child asthmatic	-0.5227	2.4784	0.142
Thigh skinfold in front at high-way point (mm)	Child not asthmatic	0.4127	11.6080	
	Child asthmatic	-1.3483	7.2615	0.161

DISCUSSION

The asthmatic children had lower birth weight but were born only slightly earlier than other children. Only eight children in the OU MCH sample were born preterm (born before 37 weeks), so this study cannot reasonably test the important of preterm versus term birth. Previous research has found preterm birth to be a risk factor for childhood asthma (von Mutius, Nicolai, and Martinez, 1993).

Adjustment for gestation makes clear that the OU MCH asthmatic children weighed less for their gestational age. In other words, they were somewhat intrauterine growth retarded (IUGR). The stand ard definition of IUGR is the lowest 10 percent of birth weights at a given week of gestation. Because of the relatively small sample size, no such cut-off is used in analyses of the OU MCH sample. Yet lower weight for gestation still associates with asthma. This is important to recognize, because it means that more subtle gradations of fetal growth impact health. Not only did the asthmatic children weigh less for gestation, but they also weighed less for their length. Birth length, adjusted for gestational age, did not differ between children that developed asthma and those that did not. The asthmatic children were thinner infants, tending toward asymmetrical rather than symmetrical growth retardation. They were more wasted than stunted. Growth retardation is associated with increased health risks of many kinds, but asymmetrical or wasted growth retardation have less risk for life-threatening complications (Ferro-Luzzi et al., 1998).

The specific anthropometric measurements show that asthmatic children were born with smaller chest circumferences and shorter trunks. Perhaps surprisingly, total

crown-to-heal length was not shorter for the infants that developed asthma, because their average leg length was also longer. Overall, the tendency to be longer but with shorter trunks and smaller chests is consistent with asymmetrical growth retardation.

Prenatal smoking by mothers did not alter the distinctive birth anthropometry of asthmatic children. Asthmatic mothers delivered about eight days earlier than other mothers, but asthma in mothers does not associate with any birth anthropometric measurements. The breakdown by ethnicity and sex of the child shows the same tendency in all subgroups. The magnitude of difference in chest circumferences was most evident in boys, however. The magnitude of short trunks and longer legs is greatest for girls.

Overall crown-rump length was shorter and legs were longer at birth for African-Americans than European-Americans. African-American infants also had smaller chest circumferences. The same tendency for asthmatic children to have been born with shorter trunks, longer legs, and smaller chest circumferences holds for both ethnic groups, so the pattern cannot be explained simply by higher prevalence of asthma in African-American children. The differences between ethnic groups are no greater than differences between asthmatic and non-asthmatic children. For example, African-American children as a whole had chests 1.9 percent smaller than European-American children, but asthmatic children had chests 3.1 percent smaller than non-asthmatic children.

The growth retardation and differences in body proportions evident in asthmatic children at birth had disappeared by the time the children were re-measured

at 4-7 years of age. Anthropometric measurements of the OU MCH children with asthma were no longer different at follow-up from those without asthma. In fact, asthmatic children had slightly larger chests at follow-up. Nevertheless, the increased asthma risk for children born lower birth weight or intrauterine growth retarded remained even after their growth caught up with other children. Lower birth weight has been associated with increased asthma even at 26 years of age (Shaheen et al., 1999).

Anthropometric results from the follow-up could be confounded by steroid medications used by asthmatic children, because poorly regulated steroid use can induce Cushing's Syndrome-like weight gain and at the same time stunt linear growth. Some studies have shown that asthmatic children may be small for their age, even if they have not had steroid treatment (Klein, Dungy, and Galant, 1991; Russell, 1994). Asthma may increase caloric needs enough to slow growth. Slower growth, however, was not detected in this study.

Two studies by the same research group in Estonia found shorter sitting height but not shorter standing height (Kivastik and Kingisepp, 1995) and smaller chest circumference (Kivastik and Kingisepp, 1997) corresponded to lower lung function in children 6-18 years old. The first study had 645 schoolchildren and the second had 1187. The pattern the Estonian group found is exactly the same as the one in neonates that developed asthma in the OU MCH sample, except that asthmatic and non-asthmatic OU MCH children were indistinguishable by anthropometry by the time they were 4-7 years old. It may be that the important growth that influences

lung function occurs prenatally, and the Estonian study with its larger sample size was able to detect differences that remained later in childhood. On the other hand, these dimensions may characterize infants and children with reduced lung growth regardless of when the growth impairment occurs. The OU MCH children may have been influenced prenatally whereas environmental factors after birth may have been more important in determining lung growth in the Estonian children.

Most of the risk factors explored in the Set 1 Hypotheses are presumed to relate to immune function. Asymmetrical fetal growth on the other hand, may predispose to asthma through a different pathway, reduced lung function. The Estonian researchers looked at lung function rather than atopy or asthma and found smaller chests and shorter thoraxes corresponded to lower lung function in health children (Kivastik and Kingisepp, 1995; Kivastik and Kingisepp, 1997). Another study found birth weight adjusted for gestational age was positively associated with lung function (Rona, Guilliford, and Chinn, 1993).

Nevertheless, reduced fetal growth can also impair immune function. Children born small for gestational age usually outgrow their immunodeficiency, but the effects can last al least until children are at least 9 years old (Ferro-Luzzi et al., 1998). As noted above, increased risk of asthma for lower birth weight infants can last into adulthood.

Social and Family Stressors

Hypothesis 10—Asthma will be more common in children born into difficult social situations.

Hypothesis 10a—Asthma will be more common in children of single mothers.

Hypothesis 10b—Asthma will be more common in children of less educated mothers.

Hypothesis 10c—Asthma will be more common in children in families with less income.

Hypothesis 10d—Asthma will be more common in children whose families have less income or receive government assistance.

Hypothesis 10e—Asthma will be more common in children whose mothers were unhappy or ambivalent about their pregnancies.

ANALYSES

Several indicators of family situation are listed in the tables that follow. Table 35 addresses the marital status of mothers. Women classified as "married" include all women living with a male partner regardless of legal status. In the follow-up (T3), women legally married but voluntarily separated are counted as single and women married but separated involuntarily are counted as married. The main reason couples were separated against their wishes was that the husband was in prison. One husband was away in military service. Prenatal (T1) marital status associates with later asthma in European-American children. European-American children with asthma were 4.3 times more likely to have been born to a single mother (0.006). Mother's prenatal marital status is not significant for later asthma in African-American children, but the trend is for more children of married mothers to have asthma.

Asthma percentages by mothers' marital status at the follow-up interview are listed in Table 35. Again, having a married mother was protective only for European-

American children (p=0.020). The same pattern among African-Americans holds at T3, with slightly more asthma among children with married mothers.

The bottom of Table 35 looks at whether the mother was married to the index child's biological father at the time of the follow-up interview. Here, the relationship is significant for both ethnic groups—although the effect is in the opposite direction for European-Americans and African-Americans. European-American children with asthma were more likely not to live with both their biological parents (0.023). African-American children were 2.6 times more likely to have asthma if they lived with both their biological parents (p=0.019).

Mothers' education is not associated with asthma in children (Table 36). There is no difference in T1 education level at all. By T3, mothers of asthmatic children had gained slightly more years of schooling than other mothers, particularly among European-Americans. The difference in maternal education is still small.

Household income during pregnancy associates negatively with later asthma rates in European-American children (Table 37). Later asthmatic European-American children were born into families making only 58 percent of what other European-American families made (p=0.013). That was $5,416 less. Among African-Americans, children with asthma were born into households with 53 percent more income (0.132).

Income patterns are the same at follow-up, but the magnitude of differences between household incomes of asthmatic and non-asthmatic children is less (Table 37). Families in both ethnicities had higher incomes by T3.

Mothers of asthmatic children had more personal earned income at T3 (Table 37). The relationship is nearly but not quite significant at p=0.074. Whether a child had asthma made no real difference in earned income of European-American mothers, but African-American mothers of asthmatic children earned more than twice as much as African-American mothers whose child did not have asthma (p=0.083).

In European-American households, those with asthmatic children were more likely to have been receiving government assistance when the follow-up interviews were conducted. Households of asthmatic African-American children received less government assistance than households of African-American children without asthma (p=0.029). Of African-American children, those with asthma were only 60 percent as likely to live in households receiving government assistance. In these analyses, government assistance includes AFDC, Social Security, disability, subsidized housing assistance, or food stamps but does not include Medicaid or daycare assistance.

In their first prenatal interview, mothers reported on how they felt about being pregnant. Mothers that said they were ambivalent or unhappy about having a baby are grouped in analyses as "not happy." A comparison of happy to not-happy mothers (Table 58) shows children of mothers that were not happy twice as likely to develop asthma as children of happy mothers (p=0.034).

Table 35.

MOTHER'S MARITAL STATUS AND PRESENCE OF BIOLOGICAL FATHER			Percent with Asthma	χ^2 p-value
T1 MOTHER'S MARITAL STATUS				
ALL MOTHERS	N=52	Married	15.38	
	N=76	Single	28.95	0.076
EUROPEAN-AMERICANS	N=35	Married	8.57	
	N=27	Single	37.04	0.006
AFRICAN-AMERICANS	N=11	Married	36.36	
	N=44	Single	25.00	0.449
T3 MOTHER'S MARITAL STATUS				
ALL MOTHERS	N=71	Married	18.31	
	N=50	Single	28.00	0.207
EUROPEAN-AMERICANS	N=47	Married	12.77	
	N=15	Single	40.00	0.020
AFRICAN-AMERICANS	N=17	Married	35.29	
	N=31	Single	22.58	0.343
T3 WHETHER CHILD LIVES WITH BIOLOGICAL FATHER				
ALL CHILDREN	N=65	With father	21.54	
	N=64	Without father	25.00	0.642
EUROPEAN-AMERICANS	N=46	With father	13.04	
	N=15	Without father	40.00	0.023
AFRICAN-AMERICANS	N=13	With father	53.85	
	N=44	Without father	20.45	0.019

Table 36.

MOTHER'S YEARS OF EDUCATION			Mean	Std. Dev.	T-test p-value
T1 MOTHER'S YEARS OF EDUCATION					
ALL MOTHERS	N=98	Child not asthmatic	11.79	1.74	
	N=30	Child asthmatic	12.00	1.29	0.267
EUROPEAN-AMERICANS	N=49	Child not asthmatic	11.76	1.47	
	N=13	Child asthmatic	11.77	1.36	0.488
AFRICAN-AMERICANS	N=40	Child not asthmatic	12.08	1.35	
	N=15	Child asthmatic	12.20	1.32	0.380
T3 MOTHER'S YEARS OF EDUCATION					
ALL MOTHERS	N=98	Child not asthmatic	12.09	1.88	
	N=30	Child asthmatic	12.50	1.89	0.145
EUROPEAN-AMERICANS	N=50	Child not asthmatic	11.94	1.79	
	N=12	Child asthmatic	12.38	1.87	0.228
AFRICAN-AMERICANS	N=40	Child not asthmatic	12.59	1.78	
	N=16	Child asthmatic	12.53	1.93	0.459

Table 37.

INCOME			Mean	Std. Dev.	T-test p-value
T1 TOTAL HOUSEHOLD INCOME					
ALL HOUSEHOLDS	**N=80**	**Child not asthmatic**	10347.51	8726.21	
	N=24	**Child asthmatic**	8882.38	7739.69	0.231
EUROPEAN-AMERICANS	**N=42**	**Child not asthmatic**	12932.52	10450.23	
	N=12	**Child asthmatic**	7517.00	5734.22	0.013
AFRICAN-AMERICANS	**N=30**	**Child not asthmatic**	7379.70	4744.86	
	N=10	**Child asthmatic**	11269.70	10047.99	0.132
T3 TOTAL HOUSEHOLD INCOME					
ALL HOUSEHOLDS	**N=94**	**Child not asthmatic**	18529.18	15721.09	
	N=26	**Child asthmatic**	16886.35	13521.88	0.314
EUROPEAN-AMERICANS	**N=47**	**Child not asthmatic**	22498.55	19548.56	
	N=11	**Child asthmatic**	16314.18	7804.97	0.051
AFRICAN-AMERICANS	**N=39**	**Child not asthmatic**	13819.97	9389.09	
	N=13	**Child asthmatic**	17363.23	17924.43	0.253
T3 MOTHER'S EARNED INCOME					
ALL MOTHERS	**N=93**	**Child not asthmatic**	5637.26	6813.13	
	N=26	**Child asthmatic**	8719.12	9947.98	0.074
EUROPEAN-AMERICANS	**N=47**	**Child not asthmatic**	6279.04	6994.35	
	N=11	**Child asthmatic**	6544.73	7258.83	0.455
AFRICAN-AMERICANS	**N=38**	**Child not asthmatic**	5188.16	6838.28	
	N=13	**Child asthmatic**	10473.08	12431.05	0.083

Table 38.

T3 WHETHER HOUSHOLD RECEIVED GOVERNMENT ASSISTANCE			Percent with Asthma	χ^2 p-value
ALL CHILDREN	N=77	Not on assistance	24.68	
	N=50	Received assistance	22.00	0.729
EUROPEAN-AMERICANS	N=49	Not on assistance	16.33	
	N=13	Received assistance	30.77	0.241
AFRICAN-AMERICANS	N=22	Not on assistance	45.45	
	N=33	Received assistance	18.18	0.029

Table 39.

T1 MOTHER'S FEELINGS ABOUT HER PREGNANCY			Percent with Asthma	χ^2 p-value
ALL MOTHERS	N=92	Mother happy	18.48	
	N=36	Mother not happy	36.11	0.034
EUROPEAN-AMERICANS	N=53	Mother happy	20.75	
	N=9	Mother not happy	22.22	0.920
AFRICAN-AMERICANS	N=32	Mother happy	18.75	
	N=23	Mother not happy	39.13	0.094

DISCUSSION

People in difficult or dysfunctional family situations live with chronic, low-level stress. Chronic stress can cause wear and tear on multiple body systems, including compromising immune function. Sympathetic nervous system activity can suppress Th1 in favor of Th2 immune function. Therefore, psychosocial stressors affect physiological functioning in a way that can promote allergy.

One goal of this study is to look at how difficult social situations for families may be stressors that increase risk of asthma in their children. In the OU MCH sample as a whole, the trends are in the direction predicted. Asthma was 88 percent more common in children whose mothers were unmarried during pregnancy (p=0.076), and 52 percent more common if their mothers were single at follow-up (p=0.207). Prenatal household incomes averaged $1465 or 16 percent less for families in which the child developed asthma (p=0.231). There was no appreciable difference in years of mother's education or whether the household received government assistance between children with and without asthma. Twice as many mothers of asthmatic children reported during their prenatal interviews that they were ambivalent or unhappy about their pregnancies than reported they were happy (36.1 versus 18.5 percent); 81.5 percent of mothers of non-asthmatic children reported being happy about their pregnancies (p=0.034).

Division by ethnicity shows opposite patterns of asthma prevalence for European-American and African-American children and their families. Sociodemographic characteristics associated with asthma in European-American children are as expected and in the same direction as in the whole sample. European-American children were most likely to have asthma if their mothers were single or reported lower household income. European-American children whose mothers were unmarried during their pregnancies were 4.3 times more likely to have asthma than children of the same ethnicity with married mothers (p=0.006). Three times more European-American children with asthma were living apart than with their biological

fathers at the time of the follow-up interviews, whereas 87 percent of European-American children living with their fathers did not have asthma (p=0.023). European-American asthmatic children were born into families with $5416 or 72 percent less income (p=0.013). At follow-up, their families still had $1643 or 38 percent less income (p=0.051).

Family structure interrelates with socioeconomic status and indirectly affects the child's physical environment. A couple of studies have shown an increased risk of asthma for children in single-parent households (Gold et al., 1993; Hurtado, 1995). Working single parents are more likely to require childcare arrangements earlier for their infants and children. They may be less able to afford in-home care, instead opting for group centers where children are exposed to a greater number of viruses. Single parents may be less likely to have private medical insurance or able to afford regular and timely medical care. Also, single working parents may have less time to take off from work to take their children to see a physician.

A surprise in these data is that more affluent, married African-American women more often had children with asthma. Comparing prenatal and follow-up data show clearly that African-American mothers whose children later developed asthma were already more affluent prenatally. They had 53 percent higher household incomes, corresponding to an additional $3890 per year (p=0.132). The income difference was smaller by the time of the follow-up, but African-American children with asthma still lived in families with higher incomes. African-American children with asthma were 74 percent more likely for their mothers to have been married

during their pregnancies (p=0.449). At follow-up, African-American children with asthma were 2.6 times more likely to still live with their biological fathers (p=0.019).

That mothers of African-American children that developed asthma were already more likely to be married during their pregnancies means, for example, that African-American mothers of asthmatics are not seeking out partners to help them care for their sick child. Fathers were not staying around longer to help with an unexpectedly ill child. The marriages were in place before the parents could have known the child would become ill. The high prevalence among African-American children that at follow-up were still living with their biological fathers (53.9 percent) shows that the highest risk was not only among the children of married women: *the African-American children with highest rates of asthma were those whose parents were married to each other and that marriage had lasted.*

The next step to make sense of this higher prevalence of disease among seemingly better-off African-American families is to explore whether affluence or being married could actually be more stressful for some African-Americans. The possibility cannot be ignored that African-American children from poorer families are simply less likely to be diagnosed with asthma. Their mothers may have less awareness of symptoms and may be less likely to take their children for regular medical care. To address ways living with both parents or in a family with higher income could be truly more stressful for African-American children, an initial and distasteful question to consider is whether African-American fathers and husbands might detract more than add to family resources and attention to the children. But

African-American women married at follow-up reported household incomes 2.2 times higher than unmarried African-American women ($p=0.005$). Number of people in the household was no greater among African-American couples than singles, and they actually averaged slightly fewer children (3.18 for married versus 3.47 for single households). So more resources were available to African-American children if their mothers were married. African-American households did not differ in average number of smokers by whether the mother was married. The statistical data, then, do not support a hypothesis that husbands drain more than they contribute in African-American families. More compelling is the ethnographic evidence. Several married African-American women expressed sentiments of being fortunate to have a "good man" and showed evident affection for their husbands. In sum, there is no evidence for blaming African-American husbands and fathers for being the source of social stress in their families.

An alternate possibility is that pressures from outside the nuclear family are greater or more difficult to cope with for married and more affluent African-American women and their families. In the second summer of follow-up interviews, mothers answered questions about their experiences related to their ethnicity and racism. Each of 57 mothers was asked whether she thought people of her ethnicity were discriminated against and whether she herself had ever felt discriminated against because of her ethnicity in housing, school, jobs, or anywhere else. Table 40 breaks down responses by ethnicity and marital status. Slightly more single women in general felt they had been held back by racism, and almost three times as many

African-American than European-American women believed racism had influenced their lives. Marital status by ethnicity shows opposite trends in answers given by European-American versus African-American women. Among European-American women, single women were three times more likely to have felt discrimination had held them back (p=0.147). Among African-Americans, though, married women were 41 percent more likely to report racism had influenced their lives (p=0.183). The sample size is small, but the tendency is for European-American women to have felt more discrimination if they were single and African-American women to have felt more if they were married.

Table 40.

T3 MOTHER'S PERCEPTION OF WHETHER SHE HAD BEEN HELD BACK BY RACISM			Percent not affected by racism	Percent affected by racism	Chi^2 p-value
ALL MOTHERS	N=29	Single	41.38	58.62	
	N=28	Married	60.71	39.29	0.144
	N=21	European-American	76.19	23.81	
	N=29	African-American	31.03	68.97	0.002
EUROPEAN-AMERICANS	N=7	Single	57.14	42.86	
	N=14	Married	85.71	14.29	0.147
AFRICAN-AMERICANS	N=21	Single	38.10	61.90	
	N=8	Married	12.50	87.50	0.183

Women told us anecdotes of times they had been faced with racism and how they coped. Contrasting stories of the way two African-American women dealt with racist encounters illustrate how their family situations influenced their abilities to

protect themselves from a hateful environment. The first woman was single and the second married. Pseudonyms are used.

> Lydia reported to us an outrageous act of racism from a community college instructor but felt the experience had little impact on her life. She dropped out of an associate's degree program after one of her instructors there made rude comments during class about "Black people in general" and their ability to learn and be motivated. Lydia filed no formal complaint and did not even tell the instructor how much his comments had hurt her—she simply dropped the class and quit going to school. She was convinced that nothing would be done if she complained so she did not even try. But Lydia did not regret her choice to leave school. She supported herself and her five children with AFDC and had housing assistance and Medicaid. Lydia lost the chance to get a degree that might have been valuable to her, but she was able to remove herself from the ugly environment without jeopardizing her ability to support her family.
>
> Marina had an experience with racism very similar to Lydia's, but she did not have the option to walk away. Marina had been married for eleven years, and she and her husband were buying their house. Marina had worked for a major discount retailer for more than three years. After she heard a European-American checker call the African-American assistant manager a "nigger" and refuse to follow his orders, she wrote a letter of complaint to the top level store manager, an European-American man. The manager took no action against the checker or in support of his assistant manager. Marina felt very uncomfortable working alongside the rude and hateful coworker. She had to see him and talk to him nearly every day. But she could not afford to quit working or even change jobs. Marina and her husband had a mortgage to pay that took both their salaries, so she needed to keep her hourly pay rate that included several tenure raises. She was also afraid to give up her medical insurance, because her daughter had asthma and she was afraid the pre-existing condition might not be covered under a new insurance policy.

On the surface, Lydia would seem to have been more affected by the racist incident with her instructor because it changed the course of her life. She dropped out of college. Marina did not quit her job, so her status was unchanged at a surface level by the racist comment from her co-worker.

But Marina was the one that expressed real hurt and frustration when she told us her story. She still worked with the man that used racial slurs to talk about African-Americans. She had tried to be pro-active by filing a complaint, yet her efforts came to nothing. Lydia, on the other hand, had walked away without making any protest. She was angry with the instructor but had largely put the experience behind her. She knew some people are just like that, you have to except it, and there is not much that can be done to change such people. Marina did not want to have to accept injustice and ugliness in her world. She wanted a better life for herself and her family and felt bigotry should not be tolerated. She saw it as her duty to stand up for what she knew was right, but felt betrayed when the store manager would take no action on her complaint. An emotion-based or avoidance coping style, like Lydia's, has been linked to better health in rural Southern African-Americans (Dressler, 1985). An active coping style in conjunction with lack of resources to truly affect change has been associated with higher blood pressure (James et al., 1983). At an emotional—and probably a physiological—level, Marina suffered more than Lydia from her encounter with racism.

Marina's personality was different from Lydia's as well as her family situation. But personality and family arrangements and socioeconomic circumstance are not independent of each other. Marina was a striver, a woman that had found a man with whom she shared dreams and goals and together they were working to improve their circumstances, for themselves and for their children. It is, after all, a method of coping and self-protection to never have so much invested in something

that you cannot walk away. Lydia's lifestyle allowed her to cope by avoidance; Marina's did not.

More affluent African-Americans may also have increased pressure from their own families. For example, extended family members may come to them for help more often. The following ethnographic vignette illustrates.

> The Jenners lived in a large, two-story 1905 bungalow on a busy corner near the edge of the Oklahoma City Medical Center. Their house was one of several on that street that were at one time expensive homes but that had fallen into disrepair. Gloria had her first child when she was 16. She worked at a fast food restaurant to support her baby, but her mother and her father's family helped also. She married her current husband a couple of years later. He was twenty-one. Because she was still shy of eighteen, they went to Nebraska where a girl her age could marry without parental consent. She told us she had a good husband. He was a good father, too, and Gloria felt lucky to have a good man. They both started out working at a hotel, doing housekeeping and cooking. Her husband also tried maintenance and security jobs. Five years into their marriage, they switched to working in medical fields. Gloria took vocational training to become a certified medical assistant. Her husband received certification in nutrition and got a job in a nursing home. By the time we interviewed Gloria, at the age of 31, she and her husband worked as home healthcare aides. Her annual salary was $48,000 and the two of them together made $72,700.
>
> Gloria told us she and her husband made more money than anyone else in either of their families. They had been married fourteen years at the time of our interview and had one child together plus Gloria's older daughter. Darrick, our index child, was four-and-a-half years old.
>
> They would have been set for a comfortable, middle-class life. But when Darrick was little more than a year old, his father's sister died in a car accident. Gloria's sister-in-law had four children spread out in age. Her oldest daughter was already on her own but the youngest was only two months old. In addition, the older daughter had two children she had left with her mother. Gloria and her husband were the only members of his family with the resources to take in his orphaned nieces and nephews. They inherited three of his sister's children and her two grandchildren—an adolescent, a teenager, a toddler, and two babies. Eventually they tracked down the oldest

daughter, who took her two children back. Still, three children were left. Gloria's husband's step-son also stayed with them except in the summer. To help, Gloria's grandmother turned over her large two-story house to them. Even without having to pay rent, Gloria said her paychecks were spent before she could deposit them in the bank.

Gloria's son Darrick was diagnosed with asthma a few months after his cousins joined the family and they all moved into the big old house. His parents had not planned to live there long, but rearing six children proved too expensive for them to move out. The house desperately needed renovation but had room enough for everyone. It had nice features, such as a pretty carved wooden banister, but was dark and dusty. The paint on the walls was dirty and chipping and the carpeting was old. In most rooms, the carpet was in pieces laid on top of the wood floor and not stretched or nailed down. The old wood floor underneath could be beautiful if it was refinished. The Jenners were starting to think about trying to fix up the house.

Darrick was thin and gave the impression of not being very robust but seemed a happy boy. He loved to talk about his father and things his father did with him, often prefacing sentences with "My daddy . . . " Certainly, Gloria's husband was an asset to her and their son. Yet because of their success as a couple, their extended family looked to them to take on responsibility that caused great strain on their nuclear family.

No variables directly related to low socioeconomic status associated with asthma in African-Americans. If lack of economic resources increases risk for asthma in African-American children, in this sample it is through stress from extended family or is masked by under-diagnosis among the more underprivileged children. Being married and having more money may actually be stressful for some African-Americans—enough so that it influences the health of their children. Two possibilities are presented here, that racism may have a greater emotional impact on married African-Americans and that extended families may expect more help from more affluent members. Among European-Americans, lower socioeconomic position and being single are associated with more asthma in children. These findings say

something about asthma onset but also use asthma as a gauge to say something about family functioning.

Occasionally in the literature, socioeconomic indices are adjusted for in comparing between ethnic groups in order to infer that all remaining differences between groups must relate to genetics or some other less tractable factor. The findings presented here show that adjustment for indices such as income or education level cannot eliminate the social differences between ethnic groups, because the meaning and consequences of socioeconomic phenomena can differ by ethnicity.

CHAPTER 7
Set 2 Hypotheses—How Asthma Affects the Lives of Children

Hypothesis 11—Asthmatic children will be perceived by their mothers as having poorer health and will have more contact with health care professionals and poorer lung function.

Children with asthma were reported by their mothers to have generally poorer health (Table 41) than other children, to have been sick more often over the previous three months (Table 42) and to have been taken to a physician more times in the previous three months (Tables 43). Asthmatic children had also been hospitalized more times than other children (Tables 44). Only 6.25 percent of African-American children with asthma were seen by their mothers as being in excellent health, compared with a fourth of European-American children with asthma.

Although African-American children were more likely to be reported by their mothers as having been sick more times in the previous three months (49 percent versus 40 percent for European-Americans), European-American children were more likely to have been taken to a physician . Of those sick at least once in the previous three months, 87.5 percent of European-American children saw a physician compared with 51.9 percent of African-American children.

Lung function residuals controlling for height were poorer for asthmatic children (Table 45). The disadvantage of asthmatic children is statistically significant only for forced expiratory flow ($FEF_{25-75\%}$). With the sample restricted to children at

least five and a half years old, lower FEV/FVC ratio and peak flow among asthmatic children also reach statistical significance.

Table 41.

T3 MOTHER'S REPORT OF CHILD'S GENERAL HEALTH			Percent no Asthma	Percent with Asthma	χ^2 p-value
ALL CHILDREN		Sample	N=100	N=30	
	N=65	Percent excellent	61.00	13.00	
	N=50	Percent good	33.00	56.67	
	N=14	Percent fair	5.00	30.00	
	N=1	Percent poor	1.00	0	0.001
EUROPEAN-AMERICANS		Sample	N=50	N=12	
	N=36	Percent excellent	66.00	25.00	
	N=23	Percent good	32.00	58.33	
	N=3	Percent fair	2.00	16.67	
	N=0	Percent poor	0	0	0.012
AFRICAN-AMERICANS		Sample	N=41	N=16	
	N=25	Percent excellent	58.54	6.25	
	N=20	Percent good	29.27	50.00	
	N=11	Percent fair	9.76	43.75	
	N=1	Percent poor	2.44	0	0.001

Table 42.

T3 MOTHER'S REPORT OF HOW MANY TIMES CHILD SICK IN PREVIOUS THREE MONTHS			Percent no Asthma	Percent with Asthma	χ^2 p-value
ALL CHILDREN		Sample	N=100	N=30	
	N=74	Percent none	59.00	50.00	
	N=34	Percent 1 time	29.00	16.67	
	N=13	Percent 2 times	8.00	16.67	
	N=9	Percent 3 + times	4.00	16.67	0.033
EUROPEAN-AMERICANS		Sample	N=50	N=12	
	N=37	Percent none	60.00	58.33	
	N=18	Percent 1 time	30.00	25.00	
	N=4	Percent 2 times	6.00	8.33	
	N=3	Percent 3 + times	4.00	8.33	0.909
AFRICAN-AMERICANS		Sample	N=41	N=16	
	N=29	Percent none	53.66	43.75	
	N=14	Percent 1 time	29.27	12.50	
	N=8	Percent 2 times	12.20	18.75	
	N=6	Percent 3 + times	4.88	25.00	0.097

Table 43.

T3 MOTHER'S REPORT OF NUMBER TIMES CHILD SEEN BY PHYSICIAN IN PREVIOUS THREE MONTHS			Percent no Asthma	Percent with Asthma	χ^2 p-value
ALL CHILDREN		Sample	N=98	N=30	
	N=68	Percent none	56.12	43.33	
	N=35	Percent 1 time	29.59	20.00	
	N=21	Percent 2-3 times	11.22	33.33	
	N=2	Percent 4-5 times	2.04	0	
	N=2	Percent 6 + times	1.02	3.33	0.045
EUROPEAN-AMERICANS		Sample	N=49	N=12	
	N=28	Percent none	51.02	25.00	
	N=19	Percent 1 time	32.65	25.00	
	N=12	Percent 2-3 times	14.29	41.67	
	N=1	Percent 4-5 times	2.04	0	
	N=1	Percent 6 + times	0	8.33	0.048
AFRICAN-AMERICANS		Sample	N=40	N=16	
	N=35	Percent none	65.00	56.25	
	N=13	Percent 1 time	25.00	18.75	
	N=6	Percent 2-3 times	5.00	25.00	
	N=1	Percent 4-5 times	2.50	0	
	N=1	Percent 6 + times	2.50	0	0.249

Table 44.

T3 MOTHER'S REPORT OF NUMBER TIMES CHILD HAD BEEN HOSPITALIZED SINCE BIRTH			Percent no Asthma	Percent with Asthma	χ^2 p-value
ALL CHILDREN		Sample	N=99	N=30	
	N=100	Percent none	84.85	53.33	
	N=19	Percent I time	13.13	20.00	
	N=6	Percent 2-3 times	1.01	16.67	
	N=2	Percent 4-5 times	0	6.67	
	N=2	Percent 6 + times	1.01	3.33	0.001
EUROPEAN-AMERICANS		Sample	N=50	N=12	
	N=46	Percent none	80.00	50.00	
	N=11	Percent 1 time	16.00	25.00	
	N=2	Percent 2-3 times	2.00	8.33	
	N=1	Percent 4-5 times	0	8.33	
	N=2	Percent 6 + times	2.00	8.33	0.085
AFRICAN-AMERICANS		Sample	N=40	N=16	
	N=44	Percent none	90.00	50.00	
	N=7	Percent 1 time	10.00	18.75	
	N=4	Percent 2-3 times	0	25.00	
	N=1	Percent 4-5 times	0	6.25	
	N=0	Percent 6 + times	0	0	0.001

Table 45.

CHILD'S LUNG FUNCTION PARAMETER RESIDUALS CONTROLLING FOR HEIGHT			Mean	Std. Dev.	T-test p-value
ALL CHILDREN					
Forced vital capacity (FVC)	N=92	Child not asthmatic	0.0124	0.2018	
	N=27	Child asthmatic	-0.0420	0.2223	0.116
Forced expiratory volume (FEV)	N=77	Child not asthmatic	0.0169	0.2003	
	N=24	Child asthmatic	-0.0541	0.2063	0.068
FEV/FVC ratio	N=76	Child not asthmatic	0.5957	7.0177	
	N=23	Child asthmatic	-1.9684	7.8480	0.069
Peak flow	N=92	Child not asthmatic	1.7396	27.5876	
	N=27	Child asthmatic	-5.9278	29.8553	0.108
Forced expiratory flow ($FEF_{25-75\%}$)	N=92	Child not asthmatic	2.7292	25.3883	
	N=26	Child asthmatic	-9.6574	25.9549	0.015
Extrapolated volume ($VOL_{EXTRA}\%$)	N=91	Child not asthmatic	-0.5741	5.0877	
	N=26	Child asthmatic	2.0093	13.1452	0.168
CHILDREN 5 ½ YEARS AND OLDER					
Forced vital capacity (FVC)	N=58	Child not asthmatic	0.0524	0.2146	
	N=21	Child asthmatic	-0.0123	0.2386	0.141
Forced expiratory volume (FEV)	N=50	Child not asthmatic	0.0536	0.2083	
	N=19	Child asthmatic	-0.0229	0.2164	0.091
FEV/FVC ratio	N=50	Child not asthmatic	0.6357	7.6911	
	N=18	Child asthmatic	-3.1007	8.2580	0.044
Peak flow	N=58	Child not asthmatic	6.5229	28.1645	
	N=21	Child asthmatic	-6.9192	32.5111	0.038
Forced expiratory flow ($FEF_{25-75\%}$)	N=58	Child not asthmatic	6.0703	23.4279	
	N=20	Child asthmatic	-9.1398	27.5205	0.010
Extrapolated volume ($VOL_{EXTRA}\%$)	N=58	Child not asthmatic	-1.1627	4.0698	
	N=20	Child asthmatic	2.5244	13.5769	0.123

Hypothesis 12—Children with asthma will spend less time playing outdoors.

Mothers were asked how long their child played outside on a typical summer day. Answers were classified as "0" for rarely, "1" for less than an hour, "2" for one to two hours, "3" for three to seven hours, or "4" for most of the daylight hours. Student t test calculations are based on this code rather than actual number of hours children played outside. Therefore, differences in means are greater than they appear (Table 46).

Based upon a Student's ttest, children with asthma spent less time playing outside (p=0.016). The magnitude of difference was greatest among African-American children. Some might argue for another statistical method on the basis that these scores are not strictly parametric. The Student's ttest, however, is a particularly robust measure of association.

Table 46.

TIME CHILD SPENDS PLAYING OUTSIDE ON A TYPICAL SUMMER DAY			Mean	Std. Dev.	T-test p-value
ALL CHILDREN	N=95	Child not asthmatic	2.65	0.92	
	N=27	Child asthmatic	2.19	1.21	0.016
EUROPEAN-AMERICANS	N=48	Child not asthmatic	2.81	0.79	
	N=11	Child asthmatic	2.64	1.21	0.326
AFRICAN-AMERICANS	N=38	Child not asthmatic	2.39	1.05	
	N=15	Child asthmatic	1.80	1.15	0.038

Hypothesis 13—Boys with asthma will be viewed by their mothers as less masculine than healthy boys. Asthma will not affect mothers' perception of their daughters.

The questionnaire mothers answered about their children's health includes a question designed to elicit their perception of the children's engendered personality characteristics. The question is a simplification of the Bem Sex-Role Inventory (Bem, 1981). The Bem instrument presents a series adjectives and phrases that can be classified as "masculine" (instrumental), "feminine" (expressive), and undifferentiated. Bem scores are classified as stereotypically masculine, feminine, androgynous, or undifferentiated, with the assumption that androgyny is most flexible and mentally healthy. The shortened question used in this study included only masculine and feminine adjectives and only words with positive connotations. Mothers were given a choice of twenty words and asked to circle six they thought best described their child. Scores are a simple ratio of the number of masculine to feminine adjectives, with the result that higher scores represent more perceived masculinity and lower scores more femininity.

For all children, scores of boys are 76 percent higher than scores of girls (table 47). Both boys and girls scored higher than one, meaning mothers chose more masculine than feminine words to describe their children, regardless of sex. Combined, average scores for children of either sex are nearly the same for both ethnic groups. However, scores for European-Americans are differentiated more by the sex of the child. Among European-Americans, scores for boys are 86 percent more masculine than scores for girls ($p=0.002$). Scores of African-American children

are less disparate, with boys' scores only 49 percent higher than girls' scores. Table 47 shows that European-American mothers viewed children with asthma as being less masculine (p=0.044), the difference being more feminine scores for their boys (p=0.016). Having asthma had little influence on the way African-American mothers perceived their children. Asthma brings the scores of boys and girls much closer together for European-Americans but not for African-Americans.

Table 47.

T3 MOTHER'S GENDER ROLE PERCEPTION OF INDEX CHILD			Mean	Std. Dev.	T-test p-value
ALL CHILDREN	N=92	Child not asthmatic	1.7098	1.6599	
	N=30	Child asthmatic	1.3839	1.3772	0.167
EUROPEAN-AMERICANS	N=46	Child not asthmatic	1.8626	1.5659	
	N=12	Child asthmatic	1.2208	0.9657	0.044
AFRICAN-AMERICANS	N=37	Child not asthmatic	1.7438	1.8810	
	N=16	Child asthmatic	1.4604	1.7116	0.304
GIRLS	N=48	Child not asthmatic	1.2010	1.3452	
	N=14	Child asthmatic	1.1357	0.7732	0.410
BOYS	N=44	Child not asthmatic	2.2648	1.8025	
	N=16	Child asthmatic	1.6011	1.7439	0.104
EURO-AMER GIRLS	N=24	Child not asthmatic	1.1429	1.0058	
	N=4	Child asthmatic	1.3000	0.8718	0.386
EURO-AMER BOYS	N=22	Child not asthmatic	2.6477	1.7055	
	N=8	Child asthmatic	1.1813	1.0650	0.016
AFRO-AMER GIRLS	N=18	Child not asthmatic	1.5178	1.8210	
	N=8	Child asthmatic	0.9000	0.7616	0.117
AFRO-AMER BOYS	N=19	Child not asthmatic	1.9579	1.9608	
	N=8	Child asthmatic	2.0209	2.2315	0.471

Hypothesis 14—Children with asthma will have better developed language skills.

The Peabody Picture Vocabulary Test-Revised (PPVT-R) was administered to each child to assess receptive vocabulary of Standard English. Nationally standardized percentiles are compared in Table 48. Children diagnosed with asthma had 36 percent higher percentile scores (p=0.044). Scores were higher for asthmatic children in every subgroup except European-American girls. The biggest differences were in African-Americans and boys. Among African-American children, scores were nearly doubled for those with asthma (p=0.011). Boys with asthma scored 61 percent higher than other boys (p=0.019). Asthmatic African-American boys scored two and a half times higher than African-American boys without asthma (p=0.022).

Table 48.

T3 CHILD'S PPVT VOCABULARY NATIONALLY NORMED PERCENTILES			Mean	Std. Dev.	T-test p-value
ALL CHILDREN	N=94	Child not asthmatic	29.8404	28.1854	
	N=28	Child asthmatic	40.5000	30.8515	0.044
EUROPEAN-AMERICANS	N=46	Child not asthmatic	44.2826	29.6833	
	N=11	Child asthmatic	53.7273	34.1324	0.181
AFRICAN-AMERICANS	N=39	Child not asthmatic	15.8462	18.7386	
	N=16	Child asthmatic	30.6875	26.3963	0.011
GIRLS	N=47	Child not asthmatic	29.9787	29.2147	
	N=13	Child asthmatic	31.9231	26.2915	0.415
BOYS	N=47	Child not asthmatic	29.7021	27.4329	
	N=15	Child asthmatic	47.9333	33.4012	0.019
EURO-AMER GIRLS	N=21	Child not asthmatic	45.5238	33.1566	
	N=4	Child asthmatic	37.2500	36.8906	0.328
EURO-AMER BOYS	N=25	Child not asthmatic	43.2400	27.0821	
	N=7	Child asthmatic	63.1429	31.2540	0.053
AFRO-AMER GIRLS	N=20	Child not asthmatic	17.8000	18.4779	
	N=8	Child asthmatic	26.7500	22.3015	0.142
AFRO-AMER BOYS	N=19	Child not asthmatic	13.7895	19.2918	
	N=8	Child asthmatic	34.6250	30.9882	0.022

DISCUSSION

Once patients have been diagnosed with disease, particularly with a chronic disease, they then take on a sick role that includes behavioral changes and alteration of their role in society (Turner, 1987:42). The OU MCH mothers identified children diagnosed with asthma as less healthy and having been sick more in the three months prior to the follow-up interview. Asthmatic children had visited a physician more times in the previous three months and were more likely to have been hospitalized at some point since their birth. Having asthma, therefore, changed the lives of the children. At least from their mother's viewpoint, the asthmatic children were sicker more often and needed more medical care.

A potentially important observation is that asthmatic African-American children were identified by their mothers as having been sick more but taken to a health care provider less than European-American children with asthma. Only 6.25 percent of asthmatic African-American children were identified by their mothers as being in excellent health, compared to 25 percent of European-American children with asthma; 43.8 percent of African-American children were rated by mothers as being only in fair health, whereas only 16.8 percent of European-American asthmatic children were rated that low by their mothers. These ratings reflect the mother's perception, and there could be cultural differences rather than actual biological differences behind the lower health ratings provided by African-American mothers. From the standpoint of the mother and child, perception of severity exerts real influence on their lives. The African-American children may also have more severe

disease from a biomedical point of view. If so, then the African-American children with asthma are not getting the medical care they need. Their asthma may be poorly managed because of infrequent monitoring by a physician. Indeed, death rates attributed to asthma are higher for African-Americans (Lang, 1994; Sly, 1994; Sly and O'Donnell, 1997).

All parameters of lung function were poorer for asthmatic than for non-asthmatic children. The difference is more robust in the children at least five and a half years old. Lung function tests depend on the technique and effort of the child, and readings from the youngest children are probably less accurate. The real difference in lung function between asthmatic and non-asthmatic children may be greater than reflected in the data. Most of the asthmatic children were familiar with taking lung function tests or blowing into peak flow monitors, so their technique was often superior to that of non-asthmatic children.

Asthma is an obstructive airway disease, meaning that the smooth muscle of the smaller airways is constricted increasing resistance to flow. In obstructive diseases, the FVC is typically decreased, because there is a large increase in residual volume due to trapped air. FEV_1 and the FEV_1/FVC ratio are decreased as resistance to expiratory flow is increased, and it takes longer to move air out of the lungs. In restrictive diseases by contrast, FVC is decreased but the FEV_1/FVC ratio remains unchanged. That is, there is a restriction in ability to bring air into the lungs but no obstruction to expiring normally. Peak flow is also generally reduced in asthmatics. This pattern is consistent with the OU MCH lung function measurements.

The OU MCH follow-up data provide some clues to ways that families adjust to having a child with asthma. Based on mother's report, children with asthma played outside less. The question mothers answered about how much their children played outside was cross-sectional with assessment of whether the child had been diagnosed with asthma. It is hard, therefore, to disentangle whether asthma is a cause or an effect of children spending less time playing outdoors. The assumption here is that asthma changes how often children play outside rather than that playing behavior determines asthma rates. The ethnographic evidence suggests mothers intentionally kept asthmatic children indoors more. Several mothers expressed the belief that asthmatic children should not be allowed to exert too much, get too hot, or be exposed to pollen.

Time spent playing outside is addressed in the next chapter in terms of social factors other than asthma, particularly fear of crime, that influence how much time mothers allow or encourage their children to play outside. Here, the way mothers treat asthmatic children differently is the issue. African-American children in general play outside less than European-American children (Table 49, Chapter 8). African-American children with asthma play outside least of all. Lack of exercise may be a cause or at least a contributor to asthma. The belief among some mothers that asthmatic children should be kept indoors could exacerbate the disease.

Mothers viewed children with asthma as less masculine/more feminine. That is, they chose more expressive and fewer instrumental words to describe asthmatic children. The difference was particularly large among European-Americans, and

especially in the way European-American mothers viewed their sons. Asthma had little influence among African-American mothers on the way they perceived the gender identity of their children. African-American boys were rated no differently whether they did or did not have asthma. African-American mothers rated girls with asthma as more feminine. In fact, asthmatic African-American girls were the only subgroup rated as more feminine than masculine. Mothers may perceive their asthmatic children to be more delicate and less able to be active or athletic. Athletic ability may be particularly important to the way European-American mothers view their boys. More research needs to explore how having asthma affects children's self-perception. Parents need to be encouraged to empower children with asthma to be active and assertive.

Asthmatic children had larger vocabularies than non-asthmatic children. This was particularly evident for African-Americans and boys. The vocabularies of African-American children were twice as high if they had asthma. Boys with asthma scored 61 percent higher on the PPVT-R than other boys. The greatest difference is in African-American boys, who scored two and a half times higher if they had asthma.

If these results are not due to chance, then one or more of three processes must be at work. The first possibility is that children with asthma learn language faster because they play outside less and spend more time indoors and around adults. They may receive more attention from adults, particularly their parents, and that attention may contribute to learning language. Boys in American culture generally spend less

time than girls do around their mothers, with the result that girls learn language faster. (This does not deny sex difference in brain function that also contribute to differences in language learning and ability.) Children probably watch television more when they spend more time indoors. Television may also contribute to language acquisition. So asthmatic children spending more time indoors may have more exposure to language from both their parents and television.

Another possibility is that children with asthma must learn to express themselves well as an adaptation to their illness. It is hard for a parent to know just by looking when a child is having an attack bad enough to need an inhaler or a trip to the emergency room. When a child has asthma, the parents must rely on the child to communicate the severity of symptoms. One study found that, among low income families living in the United States, Spanish speaking families communicated better about issues in managing a child's asthma (Clark et al., 1990). The authors speculate that Spanish speaking parents with bilingual children going to English speaking schools may rely more on their children to translate and provide information from English sources. The balance of authority between parents and children is shifted in such families, and children have to learn to communicate effectively. Asthma in children is most effectively managed when children communicate well with their parents and help make decisions about care.

The direction of causality could also be reversed. The third possible explanation for higher PPVT-R scores among children diagnosed with asthma is that children with better communication skills are more likely to draw the attention of

their parents and are better able to tell their parents about their breathing problems. More verbal and articulate children may, therefore, be more likely to be diagnosed with asthma. Children that already spend more time indoors and around their parents may both learn language faster and also be more likely for their parents to notice respiratory symptoms.

CHAPTER 8
Set 3 Hypotheses—Social Influences on the Child's Environment

Issues in this chapter are addressed ethnographically. Presentation of evidence is inseparable from exploration of ideas, so analyses and discussion are integrated.

Hypothesis 15—Families living in poverty will be less able to avoid allergens in their home environment.

The living conditions in many homes were haunting. The environment of poverty impacts health of children in many ways, of which asthma is just one. Several children slept directly on the floor or lived in homes where the toilets did not flush or there was no running water in the bathtubs. The refrigerator did not work in one home, so the family kept meats and milk in an ice cooler. Another used a camping burner to cook on the porch because their gas stove had a leak. These conditions are a direct result of poverty.

Families that move often and rent low-cost housing have little opportunity or incentive to make modifications to reduce allergens. Families living in public housing have almost no choice of housing and little control over housing conditions. For example, one mother we interviewed had concerns that the house she lived in had old paint that might contain lead. She told us she had called the owner and the housing authority numerous times asking for either confirmation that there was no lead or to have the house tested for lead. No one had returned those calls. Next she

requested she be given another house but was told she could not be accommodated. If the housing authority cannot be relied upon to assure renters that they are not living with lead paint, then certainly renters would be unlikely to receive help with allergen sources like mold, dampness, poor air conditioning, or old carpeting.

The lowest income people interviewed did not have the tools available to clean their homes well enough keep allergen levels down. Many did not own vacuum cleaners. Few had their own laundries. Commercial laundries are expensive in urban areas but can be completely inaccessible for rural families or those in small towns, especially if they do not have a car. The descriptions below of the life and environment of two women and their children illustrate how poverty can trap people in appalling living conditions and social isolation. The women are called Reba and Joanne here, but to protect privacy, pseudonyms are used in all ethnographic descriptions.

> Reba and her three children were living in a little house in a small town south of Oklahoma City too far out to be called a suburb. The tiny, worn house with falling-in roof—the kind you might drive by and think that surely no one lived there—was the last on the street behind a strip shopping center and next door to the city animal shelter and a livestock auction facility. Electric lines ran directly from a utility pole to the front of the house, over the porch with ancient looking ceramic insulators. There was the remains of an old gated entrance in the front yard, just a couple of poles and some broken pieces of wood, and some shrubbery grown up in weeds suggesting that there might have been rose bushes at one time. On the side away from the animal shelter was another small frame house very similar to Reba's but much better maintained.
>
> The interview appointment had been arranged by calling at her cousin's house next door, as there was no phone line in Reba's house. Even though we had talked to Reba the night before, she did not remember we were coming and was confused when we arrived. Nevertheless, she welcomed us into her tiny living room. Inside was

dark and crowded, completely closed up on a stifling hot day and with no air conditioner. Reba rented from her elderly cousin next door. An old blanket was hung in the arched entrance to block view of the kitchen and back of the house. The house had been used as a dump for years. Each day her eleven-year-old son would carry some of the garbage to the curb. He had cleared out most of the living room, but they had years of accumulation around them. The smells were sometimes overwhelming. There was hardly space to step around the trash and junk in the kitchen. For a bed, Reba and her two daughters shared a bare full mattress, dirty and worn with large holes. The frame was broken, so the bed slanted steeply towards the back wall. Another twin mattress lay on the floor in a back room for the boy, but he told us he got afraid to be alone at night and usually joined his mother and sisters on the broken bed.

Reba was a tall, rather heavy African-American woman with short-cropped hair. She wore a tight scrub uniform and was bare-footed. The nail on one of her big toes was thickened and had a split in it with a piece about the come off. She bent down and wiggled the nail back and forth frequently throughout the interview. Reba's eyes seemed to bulge out, and she had trouble looking squarely at the interviewer. She spoke loudly and would blurt out short bursts of words in answer to questions. The interview was tedious, and details had to be gone back over several times for clarification. Some of her answers were prefaced with a kind of disgusted laugh, as if she had secrets unrevealed.

Reba grew up in foster care, and her first husband was an abusive alcoholic. She did not have her first child until she was thirty-one. Her current husband had been in prison throughout their marriage but was nevertheless the father of her youngest daughter. She had no car, and the town has no public transportation. She stayed in the town, though, because her only family lived there—the cousin. Reba said her cousin was "in their business" all the time but would not help with any house repairs, just insisting the rent always be paid on time. At the time of our interview Reba worked as a dietary aide in a nursing home within walking distance of her house. When we called again a couple of months later to ask about an overlooked detail from a questionnaire, Reba told us she had quit working for health reasons. She had a serious kidney problem and might need to begin dialysis soon. For care she needed to go regularly to the public University Hospital up in Oklahoma City, but transportation would be nearly impossible to arrange. Reba had not figured out a solution and was scared.

Despite the one cousin, Reba led a very isolated life. She had told us she could not afford for her children to participate in special

activities, but the older two did at least get out for school and church. They took the bus to school and volunteers from their church picked the children up in a van for Sunday school. Reba, though, had only her cousin and no way to get out into the community to make friends. She did not have the clothes to attend church.

Reba lived in a dominantly European-American town. Only three percent of students in the schools were African-American. The half dozen houses clustered on Reba's side of the street had African-American families. But walking around the neighborhood after the interview, I stopped to visit with an elderly European-American woman sitting on her porch cattycorner from Reba's home. She asked me why I had been in "that house." I explained that I was involved in a health study at the University of Oklahoma and her neighbor had helped us with the project. The woman said she did not consider Reba her neighbor, that people on her side of the street never went over where the "colored people" live. In such a neighborhood, after she quit her job, Reba's social isolation would have been almost total.

Joanne and her daughter, April, both had asthma. April's medical records note that dust and mite control measures were discussed with her mother after skin testing revealed strong reactions to dust mites. She had esophageal reflux and night seizures. She also had frequent coughing fits at night, sometimes so bad she would gag and vomit mucus. The chubby little girl with lank blond hair often slept upright so she could breath easier. Her asthmatic attacks usually started with a nosebleed. The nosebleeds had been bad enough a few times to make April anemic. The previous winter April almost stopped breathing and the paramedics came to get her.

When I asked what steps she had taken to control dust in her home, Joanne said she washed the linens in hot water, damp dusted the furniture, vacuumed under the child's bed, and used an air filter and ran the air conditioner most of the time. Yet their trailer was one of the dirtiest homes we had visited. The smells of mold and cigarette smoke were overpowering. April and her mother shared a bed. Their sheets looked like they had not been washed in a long time, if ever. Clothes were piled on the floor all around the bedroom. Both a large dog and a cat lived inside the small two-bedroom trailer with Joanne, her two children, Joanne's brother and his wife and their child.

Joanne weighed 285 pounds and had a hard time walking herself. But she did not want her children to just sit around, she wanted them outside playing. Truly, it is probably healthiest for children with asthma to play outside and be active. But Joanne did not think so in April's case, as running and playing or getting hot and sweaty would often bring on April's asthmatic attacks. She thought

> doctors would want her to keep her daughter away from outdoor allergens and not let her be too active or get out of breath. She told me about a friend's son. The little boy suffered from kidney failure, could not play, and just sat and drew or watched television. She did not want April to live like that. In front of April, Joanne said, "If the good Lord takes her from me, I'm going to know she was a happy child."
>
> Joanne had not taken the steps she claimed to keep dust mites down—that much was obvious. Plus her brother and his wife both smoked in the trailer, and they lived with two animals. Still, Joanne may have been doing the best she could by April. They lived out in the country on land owned by Joanne's parents. Her father had built a house for Joanne and her children, but the house had burned down a year before our interview. Joanne's ten-year-old son had smelled smoke in the night and pulled everyone out just in time. The whole family considered him a hero. They had been forced to move into the cramped trailer with Joanne's brother a few yards from where their house had stood. Joanne was buying the trailer and her brother's family planned to move out soon. So Joanne's housing and money situation limited her ability to control the living environment. Also, she may not have been able to really understand the level of effort needed to reduce dust mites in a house. A nurse had included concerns about Joanne's mothering abilities in April's medical records after trying to teach Joanne ways to comfort a baby other than by feeding it.

A mother in Reba's or Joanne's situation does not have the power to provide a clean and allergen-reduced environment for her children. In their cases, knowing what to do is not as big an issue as money and social isolation. Geography can restrict access to medical care. People who live away from the center of a city may have a hard time getting to a public clinic. This is a particularly difficult problem for people like Reba who have no car and no access to public transportation.

In other circumstances, knowledge can be as important a resource as income for controlling allergens. Little patient literature is available to advise mothers with limited proficiency reading. Much of the literature that is available for parents is misleading as it still emphasizes keeping windows closed to keep pollens out of the

house. Pamphlets also mention that exercise can make asthma worse and de-emphasize the benefits of activity and spending time outdoors. Patient literature is developed and distributed by for-profit, usually pharmaceutical companies. There is no money to be made in products, even just pamphlets, aimed at indigent people. So patient literature is not produced for the people whose children have highest risk of asthma and highest risk of severe disease and too often even death. A very simple, straightforward pamphlet could have helped Joanne.

Some parents with asthmatic children were motivated to help their children and had adequate income and housing to do so but lacked information. Some made efforts, but those efforts would not have been effective. For example, one mother concerned about her son's exposure to passive smoke had him lie down on the floor whenever she smoked a cigarette and felt that would protect him. Thirty-five percent of mothers with asthmatic children reported to us that no health care provider had ever given them any advice on ways to improve their child's asthma other than medication. Three times more African-Americans than European-Americans ($p=0.072$) said they had never been told anything about how to help their asthmatic child except by medication. The following is an example of a woman with inadequate knowledge about what she needed to do to reduce allergens.

> Jackie and her five-year-old son were both asthmatic. She and her husband were employed, so the total family income was well above the poverty level, and they had medical insurance. Her asthma was severe and poorly maintained. She kept a breathing machine by her bed, and she had been to the emergency room fifteen times and was admitted to the hospital three times with asthmatic attacks within one year. Yet the only effort she made to reduce allergens in her house was to occasionally vacuum her living room curtains. She said

> she had also quit keeping cats, although they still had two dogs and four puppies living in the house. She reported to us that she had never been given any further advice from a physician on changes to make to her house. Her carpet looked vacuumed, but she had old overstuffed furniture, shelves with dusty knickknacks, and many large potted plants. The bed sheets were obviously unwashed.
>
> Jackie's life had been hard, and she was proud of what she had accomplished. Her mother died when she was seventeen and she had two children by that time, so she had been forced to drop out of school and marry the father of her babies, a man that abused her for years. By the time we interviewed her at age thirty, Jackie had a position as assistant manager and cook at a cafeteria and a stable marriage. Asthma was a major concern in her life, and she said she would do anything she could to improve her health and her son's health.

In the United States, the people most likely to be unable to afford health care are the working poor. Indigent people on government assistance are usually eligible for Medicaid and can go to public clinics. The working poor, however, often have incomes too high for Medicaid eligibility and yet too low to pay for private insurance. The trend over the last many years is for companies that hire near-minimum wage employees to restrict their working hours to less than full-time. Companies are not required for provide full benefits for people who work less than full-time. Also, people in low-level jobs often cannot take paid leave or family leave. Taking their children to the doctor means losing money, an untenable option for families living at the edge of their available resources. Public clinics usually have very long waiting times, and employers may not be willing to accommodate a mother missing an entire day to take her child to a clinic. In previous research, though, low-income parents reported that family characteristics and the social and physical environment were bigger barriers to effective asthma care than were access to medical care or health insurance (Mansour, Lanphear, and DeWitt, 2000).

Once a mother takes her child to a clinic, their visit is apt to be rushed. Time is rarely taken to counsel parents on lifestyle issues. Standard advice, when it is given, often emphasizes expensive steps that are impractical for people living in poverty, such as purchasing plastic covers to encase mattresses and pillows. Simpler suggestions—making sure the child has a clean place to sleep up off the floor, removing stuffed toys from the child's sleeping area, and eliminating pets—are affordable and practical for most families and would improve symptoms for many asthmatic children.

Hypothesis 16—A subgroup of mothers lacks the awareness and empathy to recognize the needs of their children and improve their health environment.

Gender roles determine who is responsible for the health maintenance activities within the family and whether that person has enough time to manage the family's health adequately. In most families in the United States, the mother has primary responsibility for managing the health of her children. In female-headed, single-parent families, the mother is the only caregiver. The health-related activities that a mother manages will have more impact than treatment from physicians on the health of her children. Clark says, "Most sources estimate 70 to 95 percent of all health care is domestic—not professional—and women provide nearly 95 percent of all domestic care" (Clark, 1993). Mothers determine what their children eat, whether they take their medications, personal and household hygiene, and when the child is taken to a physician or other medical practitioner. The completing responsibilities and roles that a woman may have will influence her ability to manage the health needs of her children.

What types and how much of their resources parents invest discretionarily in children is hard to address adequately using demographic or survey data. Monetary estimates of spending on children's schooling, clothing, and health care are likely to measure only differences in family income rather than major differences in investment. Schooling for all children is mandatory by law and free. Few families in the United States pay for health care services directly. All children must be clothed and only the grossest favoritism in spending on clothing could be detected by survey

methods. Uncovering biased investment in children in the United States requires a closer look into the personal environments of families. Differences are generally subtle, so that the best way to detect those differences is by spending some time observing the home environment and parent-child interactions.

Dust mite exposure may not explain why asthma prevalence has increased, but it does initiate the disease and contributes enormously to severity. Studies comparing dust mite load in homes may underestimate the exposure of underprivileged children if they do not take into account the sleeping arrangements of children. Whereas middle class children nearly always sleep in beds with sheets and frames to lift the mattress off the floor, that is not true of many poor children.

Several children in the study had no bed or no clean place to sleep. For example, in one family, the parents shared a bed with full linens. The little girl shared a twin mattress with her baby sister. The mattress was filthy and worn and stained with urine and blood. The baby often wet the bed, so the older sister slept in a ball in one corner to avoid the wetness. These are examples of parental non-investment. Although these are poor families that lacked the resources available to middle class parents, these examples are extreme enough to be clearly more than just the result of poverty.

Anthropologists traditionally consider the behavior of their human subjects rational and adaptive to the physical, cultural, and social environment. So it is uncomfortable to describe some mothers as deficient. The truth is, though, that not all mothers have the capital or emotional and intellectual resources to fully meet the

needs of their children—particularly if those children are sick and have special health maintenance needs. Psychologists use the term "minimal parenting." Academics in many fields have tried to address why some people behave in ways that seem maladaptive. Ethnographic accounts look for patterns and reason in behavior. Scheper-Hughes (1992), for example, showed that rampant child neglect by mothers in a Brazilian slum was an emotional and behavioral adaptation to extreme poverty. Mothers simply did not have enough resources to keep any but the hardiest children alive. Rather than risk all their children trying to save the weak ones, they made harsh choices to invest in some children and let others die. They had adapted emotionally by accepting the need to let some children die as a hard reality of their lives. But child neglect in less harsh economic environments is harder to understand. Newberger discusses a cognitive-development model to explain different parenting styles (Newberger, 1987). She identifies four levels of parental awareness with increasing sophistication and effectiveness: (1) an egoistic (self) orientation, (2) a conventional (norms) orientation, (3) an individualistic (child) orientation, and (4) an analytic (systems) orientation. Parents at the lowest level, the egoist orientation, cannot differentiate their children's needs from their own. Newberger describes the egoist orientation as follows:

> The basis for parental activity and for understanding of the child is the child's actions in relation to the parent's needs. Child care tasks and parenting are seen as being carried out in response to external cues that effect the parent's emotional and physical comfort or that offer approval to the parent. Intentions of the child are recognized, but as projection of parental feelings, and are not separated from actions. The organizing principle is achieving what the parent wants, and the

object of socialization of the child is to maximize parental comfort (Newberger, 1987:238).

Below are two ethnographic examples of mothers from the OU MCH study that fit Newberger's description of egoist parenting.

> When we arrived at Sheila's apartment she and her children were still asleep. Her family lived upstairs in a large public housing complex. They all were curled up or sprawled in various directions on the living room floor. Sheila had a blanket and pillow but her children did not. Sheila was a very thin woman. At 87 pounds she looked almost emaciated. Sheila had four children, two boys and two girls. Her oldest daughter, age twelve, was not home. Tarsha, the index child and the youngest, was four.
>
> Tarsha was shy about talking to us and buried her head in her mother's side. Sheila pushed her away and ordered her to talk to me and do what I said. The more her mother pushed, the more Tarsha resisted. Once the other interviewer began going over the questionnaires with Sheila, I was able to talk to Tarsha with less tension.
>
> Immediately, I made a mistake by asking Tarsha to show me her room. My question confused her, because, although the apartment had three bedrooms, no space was set aside for Tarsha. Her two brothers shared a room with no furniture except one twin mattress on the floor in a corner. Some clothes and toys were scattered around the baseboards. One brother said that they only slept on that mattress sometimes. Tarsha also showed me her older sister's room. It had no furniture at all and also had clothes and toys scattered around near the walls. Sheila's room had a full sized bed up on a high frame with a complete set of linens and bed spread. The bed was neatly made as Sheila had clearly slept on the floor with the children in the living room that night. Tarsha always slept on the floor, either at the foot of her mother's bed or in the living room. Sheila's bedroom and the living room were carpeted. The linoleum floors in the other two bedrooms would have been too hard to sleep on.
>
> Tarsha had a very short attention span. Not long into the interview she began going out the front door to see what the girl from across the hall was going. The other little girl ignored her and that child's mother told Tarsha to go back inside. When I asked Tarsha if she ever likes to play alone, she said no, but "sometimes I have to play by myself because nobody want to play with me." She indicated that she had no preferences of any kind, her answers to all questions sounded totally passive. For example, after I asked repeatedly what

were her favorite foods, all she would say is "anything my Mama cook." When I asked Tarsha to show me her favorite toys, she said she did not have any. Her brother reminded her of her bicycle and a Barbie car. She agreed that they were hers and she liked them. She said she would watch anything on television and could not name a particular show. She did say she and her friends liked to pretend they robbed banks, and she would like to be a doctor or a cop when she grows up. This child's Peabody vocabulary score was in the 2nd percentile for her age.

It took more than a year to complete the interview with Helen. She cut our first interview short to take her children over to the school for the community summer lunch program. Then she moved before we could arrange another visit. The landlord answered once when we called the old number. She wanted us to let her know when we found Helen who had left in the night owing several months rent and took all the appliances. The house had been a wreck. We explained the confidential nature of our project would not allow us to reveal Helen's whereabouts if we found her. It was the following summer before we located Helen again across town. She had finally gotten a new listed phone number.

Throughout that first interview, Helen sat on the couch in her living room with an infant niece beside her. She called through the screen door for us to come in but did not get up. Televisions were on in the living room, her bedroom, and the den. She had one of the children turn the volume down in the living room. Helen's obesity made her look much older than her twenty-nine years. She had seven living children, four boys and three girls. She had also given birth to stillborn twins. Helen yelled to her children from the couch in a loud, impatient, cross voice.

The house was hot and filthy. The vacuum sample from the boys' bedroom floor picked up food, rocks, dirt, and even fecal material. They had a puppy and the littlest boy was toilet training, so the fecal matter could have been from either. The children had beds with sheets, but they slept two to a twin bed and the sheets looked like they had never been washed. When we arrived, one of the little boys showed us a Power Rangers™ figure. Later, one took a Tonka™ dump truck out in the front yard where there was one other toy, a plastic van. There were no other playthings of any kind in the house or yard. Throughout most of the hour we were in the house, Helen's three-year old boy sat in the back of the utility room sobbing behind a pile of laundry.

Markas, the index child, was Helen's fourth-born. He was quiet, somewhat shy, and very difficult to understand. His four-year-

old brother was fascinated in our measuring equipment and wanted to try everything. He grabbed the skinfold calipers and would not give them back, even when I directly ordered him to do so. His mother watched but said nothing. I had to wrestle the calipers from him, and he was strong and fought aggressively. The children seemed desperate for attention and anything new to think about.

The interview continued a year and a couple of dozen calls later. I knew I would need a plan to keep the children occupied so I could talk to their mother, so I offered to bring pizza. Helen said to be sure to bring a lot, because she had nine children in the house and would want some, too. I brought three large pizzas and three two-liter bottles of drinks. Helen answered the door this time but immediately sat back down on the couch and told me to put the pizzas on the breakfast room table, indicating she thought I was a bit late. Then she called the children to come feed themselves. They did not open the drinks, and no glasses seemed to be available except one Helen had. The temperature outside was about 105°F, and inside was nearly unbearable. All the windows were closed, and the one window unit air conditioner was not working. Actually, the only problem with it was that the plastic turn knob was broken off. The metal piece sticking out could have been grabbed and turned with a pair of pliers or vice grips. The landlord could have fixed it, or Helen could have borrowed pliers from a neighbor or bought a pair. Nevertheless, the family had gone without air conditioning for four months, throughout the hottest summer on record in Oklahoma. Helen had a large box fan right next to her, the only fan in the house, blowing two feet from her face but on no one else. She yelled for her niece, a girl of about thirteen, to bring her iced drinks but never offered any to me or had the girl fix drinks for the little children.

Markas had not been diagnosed with asthma and his peak flow was near the mean for his height and age. His only medical treatments had been for an abscessed infection that formed after he fell and scraped his forehead and later a calcified nodule that grew on his head. Tarsha did not have asthma, but her sister and one brother did. If one of Helen's or Sheila's children had a serious medical condition, they would be in trouble. Helen in particular lacked problem solving skills and both women appeared to give little thought to the collective needs of their children, much

less their individual needs. Markas's teacher had documented several serious incidents when he got out of control at school and had called Helen to insist she have her son treated for a behavior disorder. Helen viewed the problem primarily as one of getting the teacher and school off her back and did not know where to turn for help.

Egoist parenting may relate to a generational cycle of poverty and deprivation. But that parenting style is found among all socioeconomic groups. By no means were all OU MCH mothers on welfare or with little education or large families inattentive to their children or unskilled at taking care of them. The follow is an account of a woman with a socioeconomic situation very similar to Helen's. But this woman was dedicated to her children and determined that they would not need luxuries to have health and happiness.

> Glenda fit a stereotype promoted by politicians of welfare mothers. A life-long recipient of government support with five children ranging in age from a year-and-a-half to fourteen, she had never held a job for more than two weeks and never lived in a household with a grown man. Her mother also lived totally off welfare and gave birth to ten children of which eight survived.
>
> Glenda and her family lived in a small, white wood frame house. The living room was sparsely furnished with an old, very worn sofa and matching over-stuffed chair and a television on a small table in the corner. The television was going when we arrived, but Glenda turned the sound off. The only decorations in the living area were a picture of a handsome Black Jesus and another religious message. Studio photos of several of her children sat on a counter under a built-in cabinet. The only table in the house was a small one against a wall in the kitchen, and it had no chairs.
>
> The air was fresh and the temperature pleasant in the modest but clean and comfortable home. A ceiling fan was going in the living room. Glenda's landlord put new carpet in the living area when she moved in a year before. She planned to have him replace the carpet in some of the bedrooms soon and have the carpets in the other rooms cleaned. Her son Monte, the index child, slept either with his sister or on the sofa in the living room. All the children were clean, well

groomed, and well behaved. Glenda was patient with the children and more than once while we were with her told an older child to be tolerant of a younger one.

Glenda had recently taken Monte to the Children's Hospital clinic to be treated for a "tight chest." The doctor thought he might have either asthma or bronchitis but had not yet made a diagnosis. The boy was given one treatment with an inhalator to loosen his breathing, and his mother was supposed to check his peak flow daily (though she sometimes had problems convincing him to cooperate). A doctor once thought Monte's next older brother might have asthma, and Glenda pointed out that her toddler daughter had eczema on her cheek. Glenda was aware that African-American children and especially boys are prone to asthma, so she was teaching herself about the disease and having her children monitored regularly at the clinic. Later abstraction of Monte's medical chart revealed that he was diagnosed with asthma a year after our interview. Because he was not formally diagnosed at the time of our interview, though, he is not included as asthmatic in the statistical analyses.

Glenda answered questions about her life with visibly growing self-consciousness and discomfort. She said that of course it would be easier to have a husband to help out, much easier. But men move on and do not help their women any more. She had married friends, and they were not much better off than she was. A mother's work goes on all the time, and men just do not help. But she knew the Aid for Families with Dependent Children (AFDC) program would probably be cut off soon, although the legislation to do so had not yet been passed. She said it is unfair to punish children because their mothers are poor. Without AFDC women would have to do everything for themselves, including making the money. She told me, at one point, that I needed to understand that when her mother was having her family, that it was considered all right for a woman to have a big family. She said no one had ever said anything rude to her about having so many children, but she knew that many people did not approve of a woman on welfare having more than two or three children. As the second oldest, Glenda grew up taking care of her younger brothers and sisters. She was reared to be a mother and she wanted a family and a big one, because she believed small families die out. She said she wanted her own "generation" to be around forever, for her family to last long after she is gone. The smiling faces of her children when she came home were the most important things in her life.

She was in school four days a week in an AFDC-run program to refresh her high school level skills. AFDC covered childcare but sometimes her thirteen-year-old daughter watched after the younger

children at home. Like her mother, the teenager was responsive, cheerful, and affectionate toward her siblings. Glenda planned next to get job training, perhaps to become a nurse's aid. She would have to pay her own childcare once she started working. But Glenda was confident she could get by. She said she knew the $538 per month her family of six had would not sound to most people like enough to live on, but she could manage money carefully. They did not suffer. Glenda knew how to buy and cook to stretch their food budget. For example, she said that she never buys expensive name brand toilet paper but gets a good generic brand that is soft and not scratchy. They buy their clothes new. She said she and her children knew how to have fun together. They could not afford vacations as often as rich people could, but when they did take a trip, they enjoyed themselves twice as much as most people.

Newberger's third level of parenting style, the individualistic orientation, best fits Glenda. Her interactions with her children demonstrated that (in Newberger's words), "Each child is recognized to have unique as well as universally shared qualities and is understood in terms of his or her subjective reality. The parent tries to understand the child's world from the child's point of view." From the stand-point of health maintenance, Glenda knew how to take care of her children and use the resources available to her to meet their needs. The following is another example of parents that had little money or education but managed to create an enriched, loving, and healthy environment for their children.

The Mueller's lived in a simple frame box of a house out in the country northwest of the metropolitan area. When we pulled into their driveway, Amy came out on the porch and greeted us like we were long awaited relatives. She offered to help us carry in our equipment and then introduced us to her husband, who was a roofer. Amy was an obese woman with long sandy brown hair, and her husband was a pleasant looking man with leathery skin. It was a surprise to learn Amy was only twenty-six and her husband twenty-nine. Either could have passed for forty. They had three children. Damon, the index child, was not quite six. There was also his four-year-old sister,

Becky, and another little boy, Jimmy, who toddled but did not yet talk much.

On the inside, their house was comfortable. Because the whole family suffered from asthma, they had put very short pile, indoor/outdoor carpeting throughout most of the house. They also ran their window air conditioning unit in their living room nearly all the time. The combined living room and country kitchen was open and airy. The carpet in the bedrooms was still old shag, as Amy said they did not have the money to replace all the carpet at once. The small bedrooms were too cramped for thorough vacuuming, so the carpets were a little dusty. Any clutter in their house, though, was from lack of closet space to put things away. A colorful sign, hand drawn by Amy and taped at child-eye level on the bathroom door read, "Brush your teeth. Wash your hands. Take fluoride pills." The sign was illustrated with drawings of a toothbrush, soap, and pill for the children too young to read. Becky and Damon also had hand drawn chore charts on their doors with spaces to check each day of the week. Both charts were the same, listing "brush teeth, make bed, clean room, pick up toys, take medicine, and say prayers."

Damon and his family had many animals outside, and he was anxious to show them off. The menagerie included six beagle puppies, three grown beagles and two poodles, a pair of rabbits with three babies, and a small pig. There was a rooster wandering around and a coop with about a dozen chickens. The family ate the eggs from their chickens and had a fenced garden with watermelons, cantaloupes, and a variety of vegetables. Their yard was large with many shade trees and places to play. There was a large sandbox, a big trampoline, a T-ball stand, a swing set, and a little playhouse built off the end of a storage shed. Nearly everything in the yard looked worn or in some way make-do, probably things the father had built or scrounged, but it was a rich environment for children's play. After showing me his animals and playthings, Damon, a bright and imaginative boy, took me on a "tour" of all the various types of spiders in his yard.

I administered the Peabody vocabulary test to Damon out in his big sandbox, under a large shade tree. He scored in the 87th percentile for his age, one of the half dozen highest in the study sample. While I was testing and interviewing Damon, his father came out with a big glass of iced tea for me. Then his father jumped on the trampoline for a while with baby Jimmy in his arms, a way to keep an unobtrusive eye on us without interfering.

The Muellers did not have an easy life. Amy had undergone four hip surgeries relating to an injury during a basketball game in middle school but was left with degenerative joint disease in her hip that made walking difficult. She did not work, and her husband's

> roofing jobs were irregular depending on the building starts. He grossed only $15,500 the previous year, plus the family had Medicaid and food stamps. When he went out of the house to bring me iced tea, Amy told the other interviewer that she was worried because her husband had started drinking frequently. But these were people that knew how to cope, that were organized and creative in building a nice home environment, and that made their children a priority. The payoff was obvious from visiting with their small children.

Behaviors of mothers described here, such as Helen who kept a fan on herself but took no steps to provide air conditioning for her children and let her children sleep in filth, do not meet any legal criteria for abuse or even abusive neglect. Helen's children were fed, clothed, sent to school, and taken to the physican. Their survival was not threatened to any high degree, although they would be at higher risk if they fell seriously ill. An adverse condition can get out of hand quickly for a child whose mother is unaware.

The value of the ethnographic vignettes under this hypothesis and the hypothesis immediately preceding is to remind clinical practitioners of the social and socioeconomic situations of many of their patients and parents of their patients—to remind them not of the extremity but of the ordinariness of very difficult and complex situations. Clinical visits are short, often no more than five minutes is budgeted to a patient. One study of low-income children (Celano et al., 1998) with asthma found only 44 percent used medications as prescribed and 27 percent used a spacer technique too ineffective to delivery the dosage. In addition, 21 percent missed scheduled follow-up appointments. Little patient literature is available to explain what to do for an asthmatic child for parents with limited reading ability. Health care practitioners rarely have the time to go over housekeeping advice with a mother who

is limited mentally. The assumption in our medical system is that physicians and nurses provide quick diagnoses and advice to proactive patients or parents that will intelligently use the information to improve their own wellbeing. Unless an overworked social worker becomes involved, no provision is made for parents unable to understand multi-step instructions, unable to maintain a strict schedule of administering medications to their children, or without resources to alter their living environments.

Hypothesis 17—Fear of crime may be a bigger reason than television that many inner-city children spend more time at sedentary pursuits indoors.

People began staying indoors more and walking less when air conditioning became common in the 1950s and 1960s. Now, though, fear of crime keeps many parents from allowing their children outside. The result is more constant exposure to indoor allergens and less exercise, neither of which are good for lung health. The following vignettes are typical.

> One mother living alone with her daughter in a Section 8 housing complex kept aluminum foil over all her windows. She told her little girl the foil was because of their allergies, but admitted otherwise in her interview. She was fearful of the neighborhood and did not want criminals to be able to see into their apartment. Although the apartment complex had play equipment, the little girl was not allowed near it. The child usually got out only once a day, to walk with her mother to check their mail. She never left the apartment without holding her mother's hand.
>
> I interviewed a little boy in the home of his great aunt, who was also his adoptive mother. His biological mother was serving a ten-year prison sentence for possession of a stolen vehicle. She was only twenty-one and had two children. Her aunt had adopted both her children. The two children and their aunt lived in a second floor apartment. The large complex had a pool and play equipment, but the boy was rarely allowed to play outside. He told me his aunt said there were too many "bad" children in the neighborhood. The aunt expressed great concern for protecting her adoptive children from the drugs and criminal environment that led their mother astray.
>
> Kelly, a European-American girl, had one friend her age down the block, but her mother did not like her to go to the other girl's house. Carrie told us that the friend was "mixed", her mother was European-American and her father was African-American. She said the girl's mother was not home much, and her father's brothers came over. She did not want Kelly to go over to a house where there was "just a bunch of Black guys."

Brigitte lived with her parents and two brothers in a zone between two gang territories. Her parents did not allow her to play outside at all because they feared the gangs. The four-year-old girl was small and pale and her Peabody language score was far below the 1st percentile for her age. Her appearance and development were that of a two-year-old, and her mother referred to her as a toddler. The house smelled moldy and was filled with cigarette smoke, but the child spent all her time inside.

For fear of crime, Marina did not let her three daughters play outside at all. She even escorted the girls when she sent one to get the mail from the box at the end of the driveway. Her three-bedroom, detached brick house was in a stable neighborhood where most people own their home. Her street was around the corner from a large Section 8 apartment complex, but the public apartments were separated by a high chain-link fence that opened only onto a street more distant from Marina's home.

Marina was a large woman, five-six and 225 pounds, who reached menarche when she was nine. Her daughters were also very developed for their ages, so their mother worried they might attract more attention from boys and men than they were ready to handle. One girl did household chores throughout our interview. She vacuumed the living room, mopped the kitchen, and cooked some soup on the stove. She had the beginnings of a curvy figure and wore a bra. I took this girl to be Marina's thirteen-year old, but near the end of the interview met her and learned she was Marina's middle child, a not-quite nine-year old who would be starting third grade in the fall. The girl took me on a tour of the house and showed me all the family photographs, identifying everyone in them. She was forthright and had impressive social graces. The precocious development of these girls and their mother's wariness about dangerous people in the neighborhood kept them in a modern version of a maiden's tower.

Crime is an important social issue but also has health consequences. Obviously, the direct effects of specific criminal acts (death, injury or psychological stress) impact health. But the current ideology of high crime rates is more extreme than the reality. The cultural reaction to fear of crime has been dramatic. The biggest effect of crime on quality of life comes from fear and distrust. Many people live isolated, fearful lives. Fear of crime contributes to ill health, especially among

children, because children spend an increasing amount of their time indoors watching television rather than venturing out into the world.

African-American children spent less time playing outside than European-American children did (Table 49). The ethnic difference in how much time children played outside cannot be explained by family income, education level of the mother, condition of the home, or the visually assessed neighborhood condition. Interviewers assessed whether each child's home had an outdoor area good for playing. That place could be the yard in front of or behind a house, a nearby park, or a playground at an apartment complex. Safety and level of traffic were considered, as was availability of shade. Each home was rated as having a good place to play, fair place to play, or no place suitable for playing outside. Of European-American children, 81 percent lived in homes with a good place to play. By contrast, only 61 percent of African-American children had a good place to play. Twice as many African-American children lived where they had only a fair place to play (35 percent versus 17 percent for European-American children). A "fair place to play" might be an unfenced yard on a street with enough traffic that close adult supervision would be necessary or a safe fenced yard with no shade or interesting features or anything to do. African-American children were no less likely—in fact slightly more likely—to live in a freestanding single-family house (71 percent of African-American versus 65 percent of European-American children). However, twice as many African-American children lived in large apartment complexes (23 percent versus 12 percent of European-American children). European-American children that did not live in a

house were more likely to live in a duplex or trailer house. Only 37 percent of large apartment complexes had good places for children to play, whereas 79 percent of houses had a good place to play, 75 percent of duplexes did, and all trailer houses had good places for children to play.

Table 49.

TIME CHILD SPENDS PLAYING OUTSIDE ON A TYPICAL SUMMER DAY			Mean	Std. Dev.	T-test p-value
ALL CHILDREN	N=59	European-American	2.78	0.87	
	N=53	African-American	2.23	1.10	0.002
GIRLS	N=26	European-American	2.81	0.75	
	N=27	African-American	2.07	1.21	0.005
BOYS	N=33	European-American	2.76	0.97	
	N=26	African-American	2.38	0.98	0.075

It would be a mistake, however, to think that housing type and availability of good play places explains the ethnic difference in how much time children spend playing outside. They must have some importance, but there is no direct statistical association between type of housing and time spent playing outdoors. Similarly, there is no direct correlation between the interviewers assessment of an available place to play and how much time mothers reported their children played outside. A large ethnic difference in amount of time children play outside could influence asthma rates and especially influence asthma severity.

Asthma rates began to climb about the time air conditioning became common in American households. Lifestyles began to change. It is unlikely that changes

initiated by air conditioning alone brought on the asthma epidemic, but they surely contributed. People got used to the comfort of being cool. Air conditioning began a cascade of social changes and changes in residential patterns. Front porches were eliminated from new houses. People in suburbs no longer felt the need to live within walking distance of businesses. Television came along about the same time and gave people something to do indoors. But concentration of urban poverty, growing attention to crime rates, and actual crime rates have also had enormous impact on childhood. Many children are not allowed outside. They are not lazy children, nor are they mesmerized by the television. Their parents are simply afraid.

If spending most of their days indoors is a health threat for children—and the balance of evidence indicates it is—then it is important to understand why children play outside less and less. The real causes have to be understood and addressed before behaviors can be changed, trends reversed. Television usually receives the blame for keeping children indoors. Watching television or playing electronic games is what children do when they are inside but is often not what keeps them in. Simply advising parents to turn off the television will not change behaviors if the real problem is that they do not have a safe place for their children to play. When new public housing projects are built, open shaded space with play equipment needs to be included—and those play places need to be located where parents can see from inside their apartments. Security should be a priority, too. Children will make friends and play outside if they have an interesting place to go and their parents will let them.

CHAPTER 9
Limitations and Potential Problems

Research methods are usually classified broadly as qualitative/ethnographic or quantitative/survey. The quality of research methods is gauged by the twin concepts of validity and reliability. Validity refers to whether the research really measured what was intended. Reliability refers to whether the results can be repeated, in the same population or another.

This research project incorporates elements from several methods, blurring the distinction between ethnography and survey. Open-ended questions are supplemented by standardized survey questions. The different elements have different strengths and weaknesses in validity and reliability, and the blending of methods helps balance the weaknesses of different components.

Ethnography has strong validity. The rich context of ethnographic information increases the chances that ethnographers are really measuring what they think they are. The reliability of ethnography tends to be weak, however, as most ethnographic research cannot be repeated. Traditional participant-observation has a systematic bias, because it leaves out people that are not part of a group. Participant observation ethnography might miss people with few social connections, such as the unemployed or people that do not go to church. As the women in this study were enrolled during their prenatal care and nearly all pregnant women in Oklahoma

receive at least some prenatal care, the original study sample held sampling bias to a minimum.

Survey and ethnographic methods serve different research needs. Survey methods have better reliability. The type of information gathered is uniform, which helps in comparing people and groups. Surveys have the additional advantage of being much faster, so they more easily yield the larger sample sizes needed for analyses to reach statistical significance in supporting or refuting hypotheses.

Survey methods have weaknesses, however. With highly structured questionnaires, researchers cannot expect to learn much more than they set out to learn. Hypotheses must be fully developed from the beginning, as there is little room for serendipity. Researchers cannot learn more than they knew to ask about at the beginning. Surveys also reveal little about the context of the data, and the validity of surveys can be questionable if the questionnaires were not designed with great care. People may not be truthful, for example, about such sensitive issues as sexual behavior or illegal drug use.

This project incorporates textual and demographic data. The validity of textual and demographic data relies on the quality of the sources, including their completeness. Textual research includes review of documents, such as the medical records abstracted in both the OUHSC Pregnancy Study and the OU MCH Study. If record keepers are not thorough, important data will not be there for abstraction. Demographic data often suffers from inaccuracies. The crime data, for instance, depends on police records, but the quality of police record keeping may be imperfect.

A more systematic source of bias may be that crime victims in some neighborhoods are more inclined to report an incident while those in other areas are less inclined.

SYSTEMATIC THREATS TO INTERNAL VALIDITY

Sources of systematic internal validity error include selection bias, information or observation bias, and confounding. Selection bias occurs when the relationship between a disease and exposure is different for study participants from among those not included in the study. Social factors can bias who participates in study samples. Who is lost to follow-up in longitudinal studies is usually not random, and the health profiles of those lost may be different from those that participate. Measurement errors or misclassifications can lead to information bias. Confounding, according to Rothman and Greenland (1998:120), ". . . [M]ay be considered a confusion of effects. Specifically, the apparent effect of the exposure of interest is distorted because the effect of an extraneous factor is mistaken for or mixed with the actual exposure effect (which may be null)." Confounding can overestimate or underestimate an effect, or even change the direction of an effect.

Selection bias

Selection bias had the potential to influence the make-up of this study sample at several stages of recruitment and follow-up. The original OUSHC Pregnancy Study had few refusals, as women were approached in a clinical setting as part of their prenatal care. Most of them viewed the research questions favorably as an extension of their prenatal care and additional concern for their wellbeing. Women

included in the final pregnancy study sample completed a second questionnaire at another prenatal visit and were visited in the hospital with their babies right after delivery. Women who switched to a private prenatal care provider after the initial interview or otherwise failed to come back for a second prenatal visit, and those that delivered at a hospital away from the Oklahoma City Medical Center, were dropped from the original study.

The complexity of their family lives influenced which mothers and children were available to participate in the follow-up interviews. For the OU MCH Study, the original 1249 participants (later reduced to 1208 because of missing variables) were re-contacted by telephone. Researchers used the latest address, phone number, and next-of-kin records from University Hospital. Women that agreed to participate allowed a two to three hour interview in their homes. Make-up of the OU MCH sample was shaped by (1) which women could be located by phone, (2) how many of them agreed to an interview, and (3) whether the scheduled interview took place. The results of contact attempts are broken down in Table 50.

Table 50.

Results of attempts to contact each of 1249 mothers from the OUHSC Pregnancy Study:	
No good phone number available	699
Phone number good but never spoke directly with the woman	319
Woman agreed to interview but never agreed to a specific appointment	13
An appointment was made but no one was home at the agreed upon time	13
An appointment was set but later cancelled by the woman	42
Woman or child's guardian refused to allow interview	24
Interview started but never completed or major data missing	8
Interview completed	131

The most common reason for a mother and child not to have been interviewed in the OU MCH Study was that they could not be reached by telephone. Phone numbers for many women had changed since their records were last updated at the OUSHC and their next of kin could not help locate them. Up-to-dateness of the contact information depended on how recently a woman or her child received medical care at the OUHSC. It would be difficult to say whether families that could not be reached would have averaged better or worse outcomes than the sample mean. They may have included extremes on both ends of the distribution. Those that had moved out of the metropolitan area may have had better-than-average outcomes. People rarely move far without good reason, such as a job change or marriage. Others could have been hard to contact because they lost their homes, were in shelters, or died. Some mothers, though their phone numbers were the same, led such chaotic lives that we were could not get messages to them or arrange appointments. To illustrate, the father of one woman told us she lived with him most of the time but he could not say when she would be at home. He had not seen her for a couple of weeks. Being unable to read or write and having no pencil or paper, he tried to memorize the OU MCH phone number.

Most of the women reached by phone remembered participating in the original study and were amenable to further participation. The outright refusal rate was low, only 24 (10 percent) of the 231 women reached by phone. These few said they could not accommodate the time and invasion of privacy required by the research protocol. Women that refused most often cited busy job schedules and

family responsibilities. Several said they and their children were healthy and they had no interest in taking time for a medical study. Women in this category probably had better-than-average outcomes.

Others refused because of difficult circumstances. A few were distrustful and concerned the caller might be a creditor or perhaps working for an estranged spouse seeking information for a custody dispute. Some children had had traumatic experiences and their mothers (or guardians) wanted to protect them from the stress of an interview. One child had recently lost a close relative in the bombing of the Murrah Federal Building in Oklahoma City. The grandmother was afraid questions about the family might add to this child's grief. A girl was in therapy after being raped by her stepfather. A father refused because the child's mother had died and the father had terminal cancer. A husband refused to discuss the project with his wife, who had just returned home after delivering a stillborn infant.

Of women reached on the phone, a sizable number agreed to participate but were not home when the interviewers showed up at the appointed time. Some of them may have wanted to refuse but could not say so on the phone. Interviewers were thorough about getting back in touch with no-shows, however, and learned that in most cases the women had something come up expectedly or had simply forgotten the appointment. Women working in retail or fast-food service jobs had erratic work schedules and were likely to be called to work without warning. Many but not all no-shows were eventually interviewed.

As noted in the section on "Participant Characteristics," the socioeconomic profile of the OU MCH Study participant families was similar to the original OUHSC Pregnancy Study. There is a slight shift, though, in ethnic make-up. African-American women made up 43.5 percent of the women in the OU MCH Study but only 31.1 percent in the original OUHSC Pregnancy Study. As suggested earlier, addresses and phone numbers would have been more up-to-date for African-American women if they more often continued to use the University Hospital clinic for regular medical care. They may also have been less likely to move out of the metropolitan area. Many had extended family they may have wanted to stay near. Though the interviewers did not intentionally seek out any particular ethnic group, the larger percentage of African-American families is actually an advantage in analyses because it makes the sample size more comparable to that of European-Americans. The women interviewed in follow-up were also slightly better educated than average for the original sample. Whereas 58 percent of the original study participants had completed high school, 70 percent of those in follow-up had finished high school by the time they sought prenatal care. Better-educated women may have been more stable and easier to reach. They may also have been more receptive to participating in the study.

Information bias

Asthma studies must deal with the challenge of measuring a highly variable disease. There is no gold standard for an asthma diagnosis. This study relies on physician-diagnosed asthma as reported by mothers (or primary custodial guardians)

or as recorded in medical records. Questions relating to asthma and symptoms were posed to the mothers in several ways. Mothers were asked whether they observed their child to wheeze frequently or have a chronic cough. They were asked whether a physician had ever said the child had asthma. Further into the questionnaire, they were again asked whether they believed their child had asthma. Medical records were abstracted later. Mother's report of whether she thought the child had asthma, mother's report of physician-diagnosed asthma, mother's report of history of wheeze, mother's report of history of chronic cough, and medical chart report of asthma were printed out and compared for each child. Files were carefully reviewed by hand in every case where a discrepancy was identified. The many double-checks in this study make false-positives unlikely. Children labeled as asthmatic in analyses have all been identified as having asthma by a physician, have been treated for asthma, and have symptoms noticed by their mothers or guardians.

The greater concern in assessing asthma prevalence in this study sample is false-negative misclassification. With lower-income families, frequently uninsured, reliance on previous physician diagnosis alone could miss children that have symptoms or underlying pathology but are undiagnosed. As a very high 23.7 percent of the children were labeled with asthma, it is hard to imagine that the prevalence could be much higher if assessed in another way. Nevertheless, the possibility that some asthmatic children were missed cannot be ignored.

Another potential source of bias is that a mother whose child has had medical problems may probe her memory more. For this reason, the purpose of the study was

described to participants in general terms as concerning "child health". Specific hypotheses and conditions of interest were not revealed to mothers. Before measuring rooms and vacuuming dust samples, interviewers told the mothers they were interested in "things in homes that can cause allergies." Mothers were also told in advance that lung function measurements would be taken from them and their child. Mothers that identified their child as asthmatic knew they were asked additional questions, but those additional questions came near the end of the interview.

Women may have tended to give normative answers to sensitive questions. For example, mothers of asthmatic children were asked about their efforts to reduce allergens in the home. Perhaps loath to admit not taking steps to keep the home clean, mothers' reports were sometimes discrepant with the interviewers' visual assessment of the living environment. The same desire to conform to value norms could have induced some women to minimize their self-report of cigarette, alcohol, or drug use.

Interviewers were blind to exposures recorded previously, such as birth weight and family functioning. Interviewers may have tended to probe deeper in homes of families with the focus outcome, an asthmatic child.

Misclassification must be considered when independent variables, such as indoor air quality, are assigned using questionnaire or checklist data. Misclassification usually but not always weakens hypothesized associations. As long

as the hypothesized association is weakened, misclassification reduces the probability of a Type I error.

Confounding

A strength of the OU MCH study is the very large number of variables collected on each family; the goal was to facilitate adjustment for potential confounders. Many potential confounders are addressed in the analyses, using residuals for continuous variables and separating correlations by dichotomous variables. Potential confounders thought to be important are discussed in the testing of hypotheses.

The likelihood is great that some unknown factor confounds the relationship between maternal body mass and asthma in children. In fact, maternal body mass is more likely than not a surrogate measure for something else, with that something else being the causal element for asthma in children. Diet, activity levels, or even genetic linkage may confound the association of maternal body mass with asthma.

Social variables, too, can be confounded by extraneous factors or mixing of effects. Income, for example, is incomplete as a measure of resources available to a family. Wealth includes also maternal assets and savings or investments. Poor families tend to have fewer physical assets, but even low levels go a long way toward offsetting low income. Material goods can be acquired independent of income and purchasing power, as through gifts or by inheritance.

Even with a myriad of variables plus ethnographic information available on each family, a few potentially important areas of information were not available.

Fathers were not interviewed or examined. Biological fathers were often not available in these low-income families. Each mother was asked whether, to her knowledge, the biological father of her child suffers from asthma. Mothers also answered quantified questions on the extent the fathers participate in their children's lives. More detail on the father's health history and anthropometry would have been helpful for testing genetic hypotheses, but gathering those data was impractical. Data on siblings are similarly sparse, although again, mothers were asked whether siblings had asthma. Dietary habits, potentially important to anthropometric issues, were not collected.

RANDOM THREATS TO INTERNAL VALIDITY

Statistical testing is the main method for assessing random threats to internal validity, so sample size is the main issue. Because of the small sample size in this study, Type II errors could be made. That is, because of the sample size, statistical testing may fail to refute the null hypothesis when it should be refuted. Also, it is possible that some Type I errors have been committed. With multiple testing, the null hypothesis may have been erroneously rejected in some cases.

Random variation may occur in the measurement of variables. The lung function tests are effort-dependent on the part of the person being tested, a concern especially with young children. Asthmatic children with experience performing lung function tests might actually perform better than less experienced healthy children. This possible random variation could serve to either dilute or strengthen the

hypothesized results. For this reason, researchers underwent training in administering technique and took the best three of several measurements on each child. This potential source of random variation will primarily threaten internal validity, rather than external, because the same problem with effort-dependency exists whenever lung function tests are used.

Most of the ethnographic evidence is anecdotal so to what percent of families an observation applies cannot be determined. Some issues thought to be potentially important were uncovered after several interviews had already been completed. It was impractical to go back to families already interviewed. However, the ethnographic phenomena reported in support of the family relations and living environment hypotheses were all observed in multiple families.

MAJOR THREATS TO EXTERNAL VALIDITY

The major issues in external validity are (1) whether results can be generalized to other populations in other places and times and (2) whether the measured constructs can be generalized to larger, more practical concepts. The OU MCH Study sample, as described earlier, seems typical of lower to lower-middle class ethnically mixed populations. The Oklahoma City area could have some unsuspected elements in its environment that have not been adjusted for in this study and that are unsuspected by the researcher. Residents in this area could also be unique in some way in their behaviors and lifestyles. The demographic variables described in the

chapter on "Participant Characteristics" will aid readers in evaluating the applicability of this study to their regions.

Validity is determined more by adjusted for confounders within group comparisons than by how well the sample represents the population at large. Social issues can be so diverse and their interrelationships so complex, though, that associations found in one sample differ from the target population. The major goal of this study, however, is to elucidate phenomena that increase risk of asthma. Biological pathways underlie the social patterns. The hypothesis that more difficult economic circumstances would lead to more asthma in children is a prime example. The pattern in European-American women was as predicted—single mothers with less income had more children with asthma. A nearly opposite pattern emerged among the African-Americans in the study. Married African-American women with higher household incomes had more children with asthma. Thus, the European-American sample would have poor external validity if the social correlates were applied to the African-Americans. Inference about the biological mechanism posited to underlie the social phenomena would not be threatened, however. Whether economic pressure and racism are greater stressors for married or for single women and their children does not change the physiology of the stress response and its interaction with immune function.

Generalizability, then, is a bigger issue for the hypotheses with social dependent variables. Mothers in this study keep children with asthma inside their homes more. In the future, if public attention is drawn to a need of more exercise for

asthmatic children, then mothers may change and start encouraging asthmatic children to play outside more.

The use of surrogate measures is a key issue on construct validity. This study uses several social or environmental surrogates to infer biological exposures or processes that could not be measured directly. In essence, these environmental or behavioral measurements serve as biological surrogates. For example, interviewer scaling of cleanness, neatness, and clutter of the home and child's room is used as a surrogate for allergen concentration. Another example is group daycare used to infer increased exposure to viral infections. The inference, rather than the calculations themselves, could be confounded. For example, this and other studies assume daycare attendance reflects increased exposure to viruses. Asthma risk differing by daycare attendance might instead be caused by some other exposure. For example, children in daycare might tend to be healthier if parents keep ill children at home. On the other hand, social stressors related to parents working might increase asthma rates among children in daycare.

The variety of sources merged in this study greatly improves construct validity. The mothers' life charts, probing by interviewers for details and clarification during administration of questionnaires, plus abstraction of the children's medical charts allowed crosschecks concerning the accuracy of data and that data as recorded were measuring what was intended.

CHAPTER 10
Conclusion

SUMMARY OF MAJOR FINDINGS

The model used to frame hypotheses in the OU MCH study posits that allergen exposure, probably chronic allergen exposure, is necessary for a host to develop asthma. Allergen exposure, though, is not sufficient. The host must be vulnerable when exposed. Genetics play a large role, as certain genotypes will be more prone to developing allergic phenotypes. With asthma prevalence increasing more rapidly than population genetics could change, though, sociobehavioral forces that promote vulnerability of hosts must also be at work. As the largest increase has been in young children, this study has concentrated on prenatal and early life risk factors for asthma. The laboratory sciences work to uncover the physiological, cellular-level mechanisms of immune function and allergy. Understanding how modern urban life promotes allergy and asthma, though, requires studying sociobehavioral patterns and how behavior interacts with biology.

The major findings of this study predictive of asthma in 4-7 year old children are that: (1) maternal reproductive history and age confound the relationship between household size and asthma, (2) weight gain in mothers after pregnancy is associated with higher asthma rates in children, (3) asymmetrical fetal growth predisposes to childhood asthma, and (4) stressful social and family situations associate with higher

asthma rates in children. These findings all relate to maternal-fetal and mother-child interaction.

The "hygiene hypothesis" proposes that the modern environment does not stimulate optimum development of immune function in infants. A lack of viral, bacterial, and some allergen exposures in early infancy leaves infants more vulnerable later to allergy. Allergy is essentially an inappropriate immune response to an antigen that would otherwise pose no direct threat to health.

Laboratory studies of how immature T-cells in infants differentiate offer the most compelling argument in favor of the hygiene hypothesis. Epidemiological approaches looking at patterns of disease in different environments are less convincing. The hygiene hypothesis predicts that asthma rates are higher when people are more isolated from each other, children attend daycare less, people have less contact with animals, and they live in less crowded conditions. Yet daycare attendance has increased over the last couple of decades. Pets have become an obsession and major industry in the United States. Rural farmers that keep livestock do not keep them in the house near their infants, but urban pet owners do keep their dogs and cats in their houses. Asthma rates are rising among all groups but are especially high in inner-city communities where people live in more crowded conditions.

Many arguments that have been offered in favor of the hygiene hypothesis are based on weak inference. Some hygiene hypothesis proponents suggest asthma is rare among rural Africans, because they live in close contact with livestock. Other

characteristics of rural Africans could explain their low asthma rates, though. Rural Africans also are thin and active, eat little to no polyunsaturated fats, and have heavy parasite load. Moreover, rural African women typically have many pregnancies. Any or all of these other things could explain the rarity of asthma among rural Africans without exposure to animals being protective. Other scientists argued that lower rates of asthma discovered in Eastern Europe after the end of the Cold War could be attributed to the frequent use of daycare in communist countries. There are other sociobehavioral differences between Eastern and Western Europe that could relate to asthma risk. Eastern Europeans, for instance, tend to be thinner.

The Ball et al. (2000) study found group daycare for infants less than six months of age offered protection from asthma after age six years of age. Children in daycare got more minor viral infections. Daycare was associated with more wheeze in the short-run, though. As the biggest increase in asthma rates has been among the youngest children, something that does not offer benefit until age six is not likely to explain much of the increase in asthma. Also, group daycare is more common for children in the United States now than it was a couple of decades ago, and still asthma rates are increasing.

Analyses of the OU MCH data raise serious doubts about the validity of what has been thought of as the strongest epidemiological evidence for the hygiene hypotheses, that an infant born into a home with more children develops a stronger Th1 response and is therefore less likely to have asthma. The assumption has been that children born into larger families have less asthma because of increased exposure

to other people. The OU MCH analyses suggest instead that a mother's age, parity, and history of prior incomplete pregnancies—particularly elective abortions—are strong determinants of asthma in her child. Parity in particular may confound the relationship between number of people in the household and allergic disease.

Early exposure may truly be beneficial to immune development. The hygiene hypothesis, though, does not fit the epidemiological patterns as an explanation for rising asthma rates among children.

The finding here that a history of elective abortion increases risk of asthma in a subsequent child suggests maternal-fetal interaction in immune functioning that spans through not just one pregnancy but across a woman's history of pregnancies. Abrupt termination of an immunologically healthy pregnancy—and therefore a Th2-dominated pregnancy—may short-circuit the signals that prompt a woman's body to return to balance in Th1-Th2 functioning.

Most previous studies of fetal growth and obesity have used asthma in later childhood or adulthood as the outcome variable. No previous study looking at obesity and asthma has focused on asthma in very young children. As noted in the literature review chapter, young children have born the largest part of the increase in asthma and, of all children with asthma, 80 percent develop symptoms by the age of five years (Weitzman, Gortmaker, and Sobol, 1990). A major part of the asthma increase, therefore, results from something happening in the preschool years or earlier—perhaps even prenatally.

Higher maternal body mass associates with increased risk of asthma for children. Curiously, pre-pregnancy weight does not predict asthma in a child as well as weight gained by the mother after pregnancy. Several possible explanations for the connection between weight gain in mothers and asthma in children are discussed in the body of this dissertation. The association is highly suggestive, though, of a link between diet or activity levels and asthma.

Changes in diet and increasing obesity demonstrate a worldwide secular trend that parallels the increase in asthma. Increasing asthma prevalence follows the general pattern of a "disease of modernization": higher prevalence in developed countries than in underdeveloped ones, highest prevalence among the poor in developed countries and among the rich and middle class in underdeveloped countries. Growing evidence indicates that asthma follows the same pattern as other diseases of modernization of increasing risk with increasing overnutrition and overweight.

Asymmetrical growth retardation is identified in this study as a predisposing risk factor for asthma in childhood. In addition to being thinner for length and gestation, children that developed asthma had smaller chest circumferences and shorter crown-rump lengths at birth. They also had longer legs, so that total crown-heel length was no shorter in infants that later developed asthma. If these findings are not due to chance or confounding, then either reduced lung maturity or immunological differences or both could be to blame.

A group of medical researchers in the United Kingdom, headed by Barker (Barker, 1998), has begun to focus on how fetal programming influences secular

trends in disease. So far, heart disease, hypertension, diabetes, and certain cancers have been the major foci of fetal programming research. The OU MCH study suggests a similar approach is appropriate for asthma.

Social stressors in parents, as gauged by sociodemographic variables, increase risk of asthma in the OU MCH children. Among European-American children, those born to single mothers with lower incomes had the highest risk of asthma. African-Americans, on the other hand, showed the opposite trend, that risk was higher among children with married mothers and higher household income. Risk for African-American children was highest if they were still living with their biological fathers at 4-7 years of age. The pattern among African-Americans, which does not conform to expectations, suggests greater affluence may actually be more stressful for some African-American families. The mechanism by which stressful life situations that surely impact primarily adult lives translates into higher disease risk in children needs to be explored. Do parenting styles make the difference or might maternal stress hormones cause immunological changes in fetuses prenatally?

Other issues addressed in hypotheses in this study concern how poverty increases allergen exposure for children, how parenting styles influence the ability of parents to create a healthy physical environment for children and monitor their health needs, and how parents' fears about crime lead them to keep their children indoors. Trends in children staying indoors more may contribute to asthma through sustained exposure to indoor allergens or reduced activity levels. The trend cannot be reversed unless the reasons children do not play outside as much as they used to are

understood. Television usually receives the blame. Air conditioning, though, initiated the change in habits with people spending less time outside. Now, fear of crime is an issue. This points out how crime can affect health indirectly. Many children will not get more exercise and time outdoors until their parents are reassured that their neighborhoods are safe.

Having the label of being asthmatic and living with the symptoms of the disease changes the lives of children. The OU MCH children with asthma had poorer health as perceived by their mothers and received more health care. African-American children with asthma were seen by their mothers as less healthy than their European-American counterparts but visited physicians less. Children with asthma play outdoors less, perhaps because parents believe they need to keep asthmatic children from overexerting and away from outdoor allergens. Parents of children with asthma need to be told that exercise and outdoor air are good for their children. Children with asthma had larger vocabularies than other children. This could be because asthmatic children receive more attention from adults and, because they play outside less, spend more time around adults. Thus the added adult attention may accelerate their learning of language. Children that spend more time indoors may watch television more and learn vocabulary faster from television. Children with asthma may also learn language skills as a coping technique to be able to communicate their symptoms and needs to parents. Children probably watch more television when they spend more time indoors. Asthmatic children may learn language faster if they watch more television than other children.

RECOMMENDATIONS FOR FUTURE RESEARCH

Hygiene hypothesis

The hygiene hypothesis may be on target—this research project cannot refute it—but research that is more convincing is needed. Better-controlled studies are needed to establish whether lack of key exposures can explain allergy rates or whether the evidence for the hygiene hypothesis has been confounded by maternal parity. One strategy would be to study adopted children in order to distinguish the effects of maternal reproductive history for early exposure in the home.

Maternal reproductive history

More needs to be known about the immunology of pregnancy and how a mother's immune function can impact the developing fetus. Fetal programming is an area of active interest, but mostly in terms of anthropometrics. How a mother's immune function can "program" a fetus should also be considered. An issue separate from, but closely related to, inference in the hygiene hypothesis is how a woman's prior pregnancy history influences maternal-fetal interactions in ways that could impact immune function in the infant. This area is wide open for research. How a woman's body and particularly immune function responds to abrupt termination of a normal pregnancy needs to be studied. Future research should look at whether a woman's body compensates for prior terminated pregnancies in ways that alter future pregnancies. How elective abortions might alter immune function in women themselves also needs to be examined.

Obesity

The mechanism linking obesity and asthma needs to be deciphered. Findings in this study, linking obesity in mothers with asthma in children, suggest more is involved than abdominal obesity mechanically constricting the lungs. Laboratory research should address immunological characteristics in people relating to differences in body mass. Lifestyle elements that contribute to obesity should also be suspect. More research is needed on affects of activity and exercise versus sedentism on both immunological functioning and lung mechanics. Diet should be explored further, too. Virtually no studies have looked at a possible relation between simple caloric intake and asthma. Total caloric intake as well as specific elements of diet should be studied.

Fetal growth

Determinants of fetal growth rate need to be better understood. How certain birth characteristics increase risk of asthma in children needs to be examined. Do asymmetrically growth retarded infants bear more risk simply because they have smaller lungs? If so, why does that risk remain after their growth has caught up with other children? Instead, are there immunological differences associated with different types of growth retardation?

Social and family stress

The claim is often made that the modern stressful lifestyle leads to disease, but actually demonstrating that is difficult. From a broad, demographic view, too many other confounding exposures intervene such as diet or smoking or a host of

unknowns. Psychosocial stress has not been clearly demonstrated to account for cultural patterns of disease, although such a link surely exists.

Neuroendocrine responses to low-level chronic stress have been addressed from many points of view, including anthropological studies. Newer understanding of a link between neuroendocrine and immunological function raises the question of how chronic social stressors impact immune function. Published accounts linking emotion and disease through psychoneuroimmunological mechanisms have been directed toward short-term, controlled stressful situations such as taking exams. More needs to be learned about how living with low-level chronic stress impacts immune function.

Crime control and play areas

Ingenuity will be required to reverse the trend of people spending more time indoors. Applied social science research should look at what steps communities could take to encourage people to spend more time outdoors. Greatest control is probably in the hands of city planners. Communities need to have places for people to get out and walk. Those places need to be comfortable and shaded, especially in hot climates. They also need to be attractive and interesting. Security is important, as people will not venture out when they are afraid. Children in particular need safe and interesting places to play. Researchers and planners need to find practical, cost efficient, and effective ways to design communities where people feel comfortable and safe outside. Improvements in low-income neighborhoods should be a priority.

Allergen control

Cost-efficient ways to reduce allergen loads in low-income homes need to be identified. Better educational materials need to be made available to parents with limited reading ability. Parents that cannot afford expensive options like mattress covers or an air filtration system need to know what are the most important steps they can take to control allergens in their home.

WHY THE MODERN LIFESTYLE LEADS TO ASTHMA

Allergy and asthma are part of the second epidemiological transition, the transition away from acute infectious diseases and toward chronic diseases. Asthma is a Th2-dominated immune overreaction with some other component that makes lungs most vulnerable. Many elements of the modern lifestyle contribute to allergy by biasing the immune system toward Th2. The balance could be shifted back toward Th1 by more infectious diseases, but that is not a palatable option. Re-emergence of infectious disease may be unavoidable, but a better option is for people to adapt their lifestyles in healthy ways that will tip the immunological balance more toward a Th1 phenotype. Evidence suggests that more nutritious but lower calorie diets would help promote Th1 over Th2 immunological functioning. More physical activity would both promote Th1 and lengthen airway smooth muscles.

Asthma is consistent with other Th2 disorders such as lupus and rarely co-morbid with Th1 disorders such as Type I diabetes (Casaco, 1995). Both neurological and endocrine elements influence asthma by altering immune function.

Hyped sympathetic nervous system activity with high levels of cortisol and norepinephrine promotes Th2 cytokines. Therefore, asthma is more likely to co-exist with conditions, such as hypertension (Held, 2000), indicative of a revved sympathetic nervous system activity. Conditions like obesity that increase estrogens and progesterone and decrease androgens will promote Th2 activity and increase risk of asthma.

The modern lifestyle promotes asthma not because of pollution or probably even increased allergen exposure. Changes in diet and increasing caloric intake, decreasing exercise, lower female fertility, less exposure to key infectious diseases, immunizations, and social stressors all conspire to increase dominance of Th2 over Th1 type immune function. People in modern urban communities get outside less and are less physically active than they were even one or two decades ago. Families rely more on prepared foods and foods high in polyunsaturated fat. The easy availability of prepared foods coupled with decreasing activity levels has led to rapidly increasing rates of overweight and obesity. These changes in diet, activity levels, and body weight contribute to asthma. Children living in poverty and in single parent families have greater risk of asthma as well as other health threats. When parents deal with particularly difficult or stressful situations, the health of their children can suffer. For these reasons, childhood asthma is very much a social issue.

Appendix

RESIDUAL EQUATIONS CREATED TO CONTROL FOR CONFOUNDING VARIABLES

Linearly adjusting birth weight for gestational age:
bwres131 = bw + 2348.479660 - (144.590393*ga)
Linearly adjusting birth weight for infant's length:
bwlngth = bw + 4298.526564 - (152.889494*chlngth)
Linearly adjusting birth weight for infant's length and gestational age:
bwgalng = bw + 6258.443212 - (62.219858*ga) - (143.446024*chlngth)

Linearly adjusting child's upper arm length for age:
t3armuc = armuc - 11.015215 - (1.799352*t3agech)
Linearly adjusting child's whole arm length for age:
t3armc = armc - 20.471175 - (2.858569*t3agech)
Linearly adjusting child's upper leg length for age:
t3leguc = leguc - 10.242781 - (3.425205*t3agech)
Linearly adjusting child's lower leg length for age:
t3leglc = leglc - 18.016914 - (2.872191*t3agech)
Linearly adjusting child's total leg length for age:
t3legsc = t3legch - 28.259695 - (6.297396*t3agech)
Linearly adjusting child's forearm circumference for age:
t3forec = forearmc - 14.038508 - (0.712481*t3agech)
Linearly adjusting child's biceps circumference for age:
t3bicec = bicepc - 14.189213 - (0.728854*t3agech)
Linearly adjusting child's wrist circumference for age:
t3wrisc = wristc - 11.234883 - (0.283072*t3agech)
Linearly adjusting child's thigh at half-way point circumference for age:
t3thi1c = thigh1c - 24.368131 - (1.452760*t3agech)
Linearly adjusting child's thigh below gluteal fold circumference for age:
t3thi2c = thigh2c - 25.317226 - (1.877127*t3agech)
Linearly adjusting child's head circumference for age:
t3headc = headc - 47.724497 - (0.611204*t3agech)
Linearly adjusting child's chest circumference for age:
t3chesc = chestc - 41.429670 - (2.863984*t3agech)
Linearly adjusting child's waist circumference for age:
t3waisc = waistc - 44.289647 - (1.908882*t3agech)
Linearly adjusting child's hip circumference for age:
t3hipsc = hipsc - 17.529935 - (8.257869*t3agech)
Linearly adjusting child's biceps skinfold for age:

t3bisfc = bisfc - 6.047923 - (0.041649*t3agech)

Linearly adjusting child's triceps skinfold for age:

t3trisc = trisfc - 4.576579 - (0.822017*t3agech)

Linearly adjusting child's subscapular skinfold for age:

t3subsc = subsfc - 1.974303 - (0.919909*t3agech)

Linearly adjusting child's forearm skinfold for age:

t3armsc = armsfc - 3.287431 - (0.523823*t3agech)

Linearly adjusting child's thigh skinfold for age:

t3thsfc = thighsfc + 2.367397 - (3.098128*t3agech)

Linearly adjusting child's height for age:

t3htc = htc - 30.741741 - (2.496137*t3agech)

Linearly adjusting child's weight for age:

t3wtc = wtc - 16.717851 - (6.000621*t3agech)

Linearly adjusting child's weight for age and height:

t3wtaght= wtc + 92.138957 + (2.838227*t3agech) - (3.541010*htc)

Linearly adjusting child's trunk and head (head to rump) height for age:

t3trunc = trunk - 49.940581 - (0.032366*t3agech)

Linearly adjusting child's waist to hip ratio for age:

t3applc = applec - 0.398507 - (0.138829*t3agech)

Linearly adjusting lung function measurements for both mothers and children for height:

resfvc	= fvc	+ 1.810598	- (0.069483*htm)
resfvcc	= fvcc	+ 1.293931	- (0.050153*htc)
resfev	= fev	+ 1.778360	- (0.065414*htm)
resfevc	= fevc	+ 1.016620	- (0.042697*htc)
resfevc2	= fevc2	+ 1.694229	- (0.054738*htc)
resff	= fevfvc	- 66.955807	- (0.386754*htm)
resffc	= fevfvcc	- 119.462112	+ (0.549823*htc)
resffc2	= fevfvcc2	- 19.424660	- (1.321281*htc)
respeak	= peak	+ 74.609427	- (6.471027*htm)
respeakc	= peakc	+ 68.341755	- (4.810762*htc)
resfef	= fef	- 14.054265	- (2.855505*htm)
resfefc	= fefc	+ 81.726707	- (3.556372*htc)
resvol	= vol	- 3.663399	- (0.049452*htm)
resvolc	= volc	- 25.785401	+ (0.357563*htc)
peakaght	= peakc	+ 62.655445	- (7.050872*t3agech) - (3.776817*htc)

Linearly adjusting T1 number of people in household for number of older maternal siblings:

hygiene1 = housnum - 3.090991 - (0.439959*older)

Linearly adjusting T3 number of people in household for number of older maternal siblings:

hygiene2 = children - 2.079188 - (0.591772*older)

Linearly adjusting parity of mother for T1 number of people in the household:

parity = kidrank - 1.472790 - (0.230815*housnum)

Linearly adjusting gravida of mother for T1 number of people in the household:

gravida = pregrank - 2.22192 - (0.177185*housnum)

Linearly adjusting mother's age for previous abortions and index child's birth rank:

momage3 = t2agemo - 19.919461 + (0.437735*elabort1) - (2.226165*kidrank)

Linearly adjusting index child's birth rank for mother's age:

momage4 = kidrank + 1.343861 - (0.146355*t2agemo)

Linearly adjusting history of previous elective abortion for mother's age:

momage5 = elabort1 + 0.000975 - (0.006699*t2agemo)

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