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Early Child Development and Experience-based Brain Development - The Scientific Underpinnings of the Importance of Early Child Development in a Globalized World *

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Abstract for Brookings Institution

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By J. Fraser Mustard
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There is good evidence that humans have been engaged since the Agricultural Revolution in what some have described as experiments in civilization. Many of these civilizations have collapsed in part because of inability to adapt to economic, environment and population changes and provide the resources and governance to sustain their societies. The challenge today for humans to adapt to change is as great, if not greater, than any time in the history of the human species. To cope with the changes globally we will need to have competent, healthy, high quality populations in all regions of the world. There will have to be a substantial investment in early child development (ECD) to establish high quality competent populations to sustain and build democratic, prosperous, pluralistic sustainable communities.

To achieve reasonable equity in competence, coping skills and health will require applications of the new understanding of how the early years of child development, particularly brain development, set trajectories that affect health (physical and mental), learning, and behaviour throughout the life cycle. In developed countries such as Canada and the United States, there is considerable inequity in literacy. Nearly 50% of the adult population in these two countries is at Levels 1 and 2 in assessments of literacy (prose, document and quantitative). This level of competence is not satisfactory for adequate functioning in today's globalized world with exponential growth in new knowledge and technologies. In other countries such as those in Latin America, close to 80% of the population is at Levels 1 and 2. In African countries, competence in literacy is even lower. Experience-based brain development in the early years (conception to age 6) sets pathways in brain development that affect learning, health, and behaviour throughout the life cycle. Basic literacy skills and understanding are set during this period of development. Throughout most of the world, there is a substantial gap between what we know and what we do. Recognition of how brain development affects the competence, health, and well-being of populations gives us an opportunity to improve the quality of populations and enhance our attempts to establish prosperous, healthy, tolerant, pluralistic, sustainable, democratic societies with much less violence. Unless we find strategies to improve ECD in all societies, many societies risk slipping into chaos with negative effects on our initiatives in globalization.

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INTRODUCTION

This paper begins with a brief overview of the evolution of the human species from the beginning of the hunter-gatherer groups 200,000 years ago through to the civilizations we started to create 10,000 years ago. The competence and quality of populations is an increasingly important issue in a world with exponential growths in knowledge and technologies, population growth and changes in the age of populations and globalization. There is considerable evidence that the human brain has evolved in this period with effects on health, learning, innovation and behaviour.

We now have a good understanding of how experience-based brain and biological development in the early years differentiates neuron functions, influences the development of the sensing pathways, the neuron connections (synapses) and pathways in the brain that influence health, learning, literacy, and behaviour throughout the life cycle. The section on brain development and health, behaviour and literacy is followed by an outline of initiatives that enhance early child and brain development and some of the implications for societies in terms of the competence and qualities of populations and our continuing evolution. The paper will conclude with considerations of the importance of a good early start for children, its implications for the competence and quality of populations, the prosperity and stability of societies, and its relevance to what has been described by some as our continuing experiments with civilizations (Wright, 2004).

We now have a broad understanding of the origins and development of our species, our various social organizations and the civilizations that have been created over the last 10,000 years. The evolution of our species from other primates is considered to begin about five to six million years ago. Over the last 200,000 years our own species, homo sapiens, has evolved to become the dominant primate on our planet (Balter, 2002; Boserup, 1981; Tattersall, 1998; Calvin, 2002; Olson, 2002). In this evolutionary process, humans have developed a brain with a capacity for language, cognition, control of emotions and fear, creation (economic and social), and control of violent behaviours. We have also developed a capability to record and remember the past, the history our evolution and think about the future.

Until about 10,000 years ago, we lived as hunters and gatherers in relatively small groups in which the females largely controlled the social group involved with raising the young while the males were engaged in hunting to bring back the animal protein from their kills to help feed the group (Boserup, 1981; Tattersall, 1998; Ehrlich, 2000; Olson, 2002; Wright, 2004). These hunter-gatherer groups could get into conflict with other groups leading to the killing of members of both groups. Conflict and violence has been part of our history. Part of this conflict has been driven by the need to access resources (water and food) necessary to sustain life. Another powerful factor affecting the evolution of the human primate were changes in climate. Humans appear to have been more adaptable to climate change than the Neanderthals who were a significant primate species until about 30,000 years ago. The periodic ice ages forced most humans to migrate into warmer climates since they had until recently only limited capability to survive in very cold climates. When it became warmer, they of course could move back into the areas that were freed up from the freezing temperatures (Calvin, 2002). Humans, among mammals, became more adaptable to changes in their environment. Some, such as the Eskimos and Inuit, developed strategies to survive in a cold climate. The population of humans on the planet gradually increased during this period of evolution as hunters and gatherers eventually reaching a point where it was hard to sustain many groups or communities through hunting and gathering because of the limitation of the food supply (Boserup, 1981; Ehrlich, 2000). This led to what is described as the Agricultural Revolution about 10,000 years ago and what some consider as the beginning of our experiments in what we often refer to as civilizations (Wright, 2004).

The new agricultural communities could produce enough foodstuffs to sustain non agriculture members of a community leading to different kinds of social organization and power that gave rise to towns and cities, laws, religions, technological innovations, rulers and institutions to govern societies (Boserup, 1981; Tattersall, 1998; Olson, 2002). These urban centres were dependent on the farming community being able to produce the foodstuffs needed and transport them to be sold in the towns and cities. This led to the need for property rights, financial institutions, laws, regulations and institutions for governance. These new communities established socioeconomic hierarchies with religious leaders, priests and kings, and leaders of business enterprises and workers. The new institutional and socioeconomic circumstances of these new communities put pressures on humans to be able to better communicate with each other, establish laws and record transactions.

Languages of human primates have evolved during our continuing evolution over the last 200,000 years making it increasingly possible for communication within and among groups (Tattersall, 1998; Ehrlich, 2000; Hauser et al, 2002; Olson, 2002; Holden, 2004;). At the time of the Agricultural Revolution, we did not have symbols that we could use in communication with each other and in recording transactions and events. During the last 10,000 years of human evolution, we developed symbol systems and alphabets (Greenspan and Shanker, 2004; Ehrlich, 2000), which set up a capability to communicate with each other through writing, to record business transactions, establish laws, and record some history. This period of human evolution also led to the evolution of

religions and their beliefs. These often became a major factor in the social organization, culture and governance of the emerging civilizations.

The early civilizations that developed such as the Sumerian civilization became remarkably proficient in building new institutions and structures, developing forms of governance, laws, and systems for feeding and supporting the urban populations. However, since they had to irrigate the land to produce the food needed by the new farming individuals in their civilization, they ran into the problem that irrigation with water in hot climates causes the soil to become salinated, which decreases food production. If they understood the problem, they were unable to solve it. They could not think about and discuss their future. This led to an inability to produce the food necessary to sustain the urban populations contributing to the collapse of civilization (Wright, 2004; Diamond, 2005). This can be considered as an example of the rise and fall of a civilization in part due to the inability to understand and discuss the future and take steps to sustain the ecosystem necessary for food production.

After the Agricultural Revolution, humans in different parts of the world started to create civilizations (Kenoyer, 2003; DiChristina 2005; Wright, 2004). These civilizations or empires have included the Chinese, the Incas, the Maya in Central America, the Romans, the Egyptians, the Greeks, Native Americans (e.g. Floridians) and most recently, the British. The history for the last 10,000 years shows that there was a delicate balance between the understanding and interests of the rulers, social political organizations, and other elites and their ability to plan for the future and secure and sustain the resources necessary to support and govern and sustain all parts of their civilization. This failure has been a factor in the rise and fall of civilizations.

Our ability to communicate and develop new knowledge and technologies has continued to evolve over the last 10,000 years. For example, when some civilizations acquired the capability to build sailing vessels capable of long journeys along with the development of techniques for navigation, these societies began to explore various parts of the planet and engage in a form of globalization and empire building. Spain and Portugal's innovations in this field made them wealthy; trading with and controlling the East Indies [Spice Islands] and the Incas and Aztecs in The Americas. In all of these civilizations, there were conflicts between different groups concerned with power and access to resources. This period in our history also showed the effect of what could be best described as a form of biological warfare. The Europeans introduced viruses and bacteria that the populations in The Americas had not been exposed to. This decimated the populations making it easy for the Spaniards with small armies to conquer the civilizations in The Americas (Wright, 2004). This was also true for the effects on North American Indians of the English and French migration to North America.

Gradually, as our knowledge and capacity to innovate increased, societies became more prosperous. In Western countries during the last 250 years, we established more democratic forms of governance, and improved the health and well-being of the populations and established more stable social orders. However, this has been a slow process with continuing conflicts between nations, religions, and cultures. The

Victorians were pessimistic about the future and wondered if all the increased economic output and change made sense if for many populations it meant deracination, misery, poor health and filth. Some of these gloomy Victorians felt that this exponential growth in new technologies would eventually destroy the human race. The conflicts and destructive behaviours in the 20th century among civilizations to some extent supported the concerns of the gloomy Victorians. Early in the 20th century we started World War I, which killed about 12 million people. We then went through the Communist Revolution in Russia, the Depression, and the emergence of the Nazi power base in Germany. This led to the Second World War, leading to more than 50 million dead. It has been calculated that in the 20th century we slaughtered more than 100 million humans in conflicts. We have, in effect, managed in the 20th century through conflicts to kill twice the entire population of the Roman Empire.

To prevent continuing conflict, the ability of human beings to communicate with and understand each other, plan for the future, and control their behaviour in the diverse regions of our planet will be an important factor in the continuing evolution of civilizations and our attempts to reduce the risk of conflicts, violence, and destructive behaviours (Wright, 2004).

The advent of the printing press 600 years ago made it possible to communicate with and educate more and more members of the population in the different regions. The printing press has proven historically to be a factor in education influencing the evolution of democracy, the diffusion of ideas such as liberty, human rights, and equality (Erhlich, 2000). However, today many individuals in different parts of the world do poorly in assessments of literacy and understanding including nearly half the population in developed countries such as Canada and the United States (OECD/Stats Canada, 2000). These individuals do not have a good understanding of what the universe is, the nature of evolution, the nature of the geosphere biosphere interaction on the planet. How do we build and sustain diverse, democratic, tolerant, competent, sustainable non violent societies in an increasingly globalized world with significant variation in the understanding, competence and quality of populations?

Today, with the degree of globalization that has resulted in part from the exponential growth in knowledge and new technologies, can we continue in our experiments in civilization with minimal damage to our biosphere and better control of violence and conflict among the different population groups within societies and between societies? Can humans create global institutions of governance to allow us to continue our experiments in civilization and build and sustain stable, tolerant, prosperous, democratic societies without improving the competence and quality of all populations?

One goal has to be the creation of institutional arrangements to ensure populations throughout the world can easily communicate with each other, and understand the implications of the new knowledge for our continuing experiments in civilizations. The wide diversity in the quality of human development within countries and different regions of the world poses a massive challenge to bring all members of the human species up to the same level of well-being and competence. The inequities in health, development,

income, literacy, and the social instability and violence in different parts of the world are a serious problem for our continuing experiments in civilizations.

To achieve the goal of enhancing the competence and quality of our populations, and establish sustainable, stable, equitable, tolerant, pluralistic, democratic societies, we have to find ways to optimize human development, health, and well-being in all regions of the world. The continuing evolution and improved function of our brain will influence how well we cope with the challenges and opportunities we face today (Keating and Hertzman, 1999; Balter, 2005; Evans et al, 2005; Mekel-Bobrov et al, 2005). To do this we have to understand the development of the brain and its continuing evolution and how experience in early life affects its development.

In this paper an outline is given about how child development and experience-based brain development in the very early years of life sets biological pathways that affect cognition, behaviour (violence), capacity to learn, memory, and physical and mental health throughout the life cycle. How societies understand and apply the new knowledge about factors influencing early child development and human development will have a major effect on the competence, quality and well-being of future populations and the kind of cultures, societies and civilizations we continue to try and create. One of the major developments in our continuing experiments in civilization is the improved health and well-being of populations in developed countries since the socioeconomic changes associated with the Industrial Revolution. Part of the explanation for the improved health, education, and well-being of populations in Western countries over the last 250 years is related to the socioeconomic changes associated with the Industrial Revolution and the effects on child health and development.

EARLY CHILD DEVELOPMENT AND THE HEALTH AND WELL-BEING OF POPULATIONS IN DEVELOPED COUNTRIES

In Western countries, historical analysis of the last 250 years has shown that in association with the Industrial Revolution, countries like Great Britain became more prosperous and that this was associated with improved standards of living, social changes, and a more democratic society. These changes were associated with a reduction in the population mortality rates. McKeown (1976) by exclusion attributed the improved health during this period mainly to better nutrition of the British population. Better sanitation and clean water, he concluded, contributed to about 25% of the decline in mortality while the effect of medicine was negligible. McKeown found that death from infectious diseases such as tuberculosis and other conditions, declined in the British population long before there was any effective medical treatment or public health measures. He, however, could not, with his retrospective historical analysis, assess what the key factor or factors in society leading to improved health were. Fogel (1994, 2000), a University of Chicago Nobel Prize winner in Economics, also examined the effect on health of the socioeconomic environment that developed in association with the Industrial Revolution in Western countries. Using data from several Western countries over the last 250 years, he was able to show that as the prosperity in Western nations improved, the mean height of the population increased and the mortality rates declined. Since height is a product of genetics and nourishment when young, Fogel came to the conclusion that the improved health of Western populations during these socioeconomic changes was due in part to improved conditions for early child development. Data from Holland during this period, 1850-1910, (Drukker and Tassenaar, 1997) shows a similar pattern. As Holland became more prosperous, the mean height of the population increased along with a decline in mortality. The improved health during this period could not be attributed to health care and only partially to public health measures. This evidence from historical records indicates in Western countries that improvement in the socioeconomic environment (including better nutrition) in association with the Industrial Revolution, had beneficial effects on child development leading to improved health and well-being in adult life (Fogel, 2000; Steckel and Floud, Eds. 1997; Drukker and Tassenaar, 1997).

The factors that improved early child development in this period included better nutrition, improvements in quality of water and sanitation. Reves (1985) pointed out that the increased prosperity during this period was associated with a decline in fertility rates, an increase in child spacing and decrease in the number of children in families. All of these changes decreased the risks of infection and poor growth and development for young children.

As our databases concerning the relationship between health and the socioeconomic environments have become more established, it has been demonstrated that in developed countries in the 20th century there is a relationship between the socioeconomic position of individuals in society and their health and well-being (Adler and Ostrove, 1999; Kawachi, Kennedy and Wilkinson, 1999; Davey Smith, 1997; Marmot, 2004). This relationship is referred to as a socioeconomic gradient in health (Figure 1). In recent

studies in developed countries, socioeconomic gradients in behaviour, literacy, mathematics, and language skills (Keating and Hertzman, Eds., 1999; Heymann et al, Eds., 2005) have been found. It is important to appreciate when considering gradients in developed countries that they tend to be linear; that is, each step up in the socioeconomic scale of a developed society, the better the health, language, literacy competence and well-being of the population. Thus, the socioeconomic determinants of health are not simply a question of poverty but a question of where you are in the socioeconomic hierarchy and how this influences your development and vulnerability to illness over the life cycle. What factors in the social environment contribute to the vulnerability of individuals in all social classes and why is it greater for the population in the lower socioeconomic sector?

In the detailed study of the health and well-being of the civil servants in Whitehall in the United Kingdom, Marmot and his colleagues (Marmot and Davey Smith, 1991; Marmot, 1996, 1997, 2004; van Rossum et al., 2000) have shown a clear gradient in health as measured by death in relation to position in the job hierarchy of the British civil service (Figure 2). Those in the top positions in the civil services have the lowest mortality rates, while those at the bottom have higher mortality rates (all the data in these studies were adjusted for age and sex). Another striking feature of this study is that the causes of death range from cardiovascular disease and strokes to suicides. In these studies, they found that psychological factors around the nature and control of work were as important as the conventional risk factors for coronary artery disease. Marmot, in reviewing the risk factors for cardiovascular mortality in the U.K. civil service, concluded that plasma cholesterol levels could not account for the social gradient in coronary heart disease. It was a predictor of coronary heart disease mortality within each employment grade but did not explain the gradient. Smoking in this study showed a clear social gradient but the gradient for coronary heart disease was similar in non-smokers as in smokers. They concluded that the conventional risk factors accounted for only about one third of the deaths in the employment grade gradient for coronary heart disease (Marmot, 2000).

Other population-based studies have shown similar socioeconomic and job related patterns of health (Lynch, 1981; Adler and Ostrove, 1999). It is important to remember that all the members of the civil service in Marmot's studies are paid (no poverty), educated to varying levels and live in a culture with a national healthcare system. The individuals in the civil service study are members of the British middle class. These gradients in health as measured by death are obviously not caused by a population living in poverty or a population with poor access to healthcare.

Marmot chairs the new WHO Commission on Social Determinants of Health. In his article in relation to the role of the Commission, he states,

> "Treating existing disease is urgent and will always receive high priority but should not be to the exclusion of taking action on the social determinants of health." He goes on to state, "inequalities in health between and within countries are avoidable…There is no necessary biological reason why life expectancy should be 48 years longer in Japan

> than in Sierra Leone or 20 years shorter in Australia Aboriginal people than in other Australians." (Marmot, 2005).

A significant factor in the improvement in health in the developing world has been improvements in nutrition, water and sanitation and medical interventions such as oral re-hydration therapy that has decreased the complications of diarrheal diseases (Brainard, 2005). Obviously, vaccination programs such as the smallpox vaccine have been a significant factor in improving outcomes for young children. It is interesting that these initiatives have reduced maternal and infant mortality and have lowered the life expectancy gap between the rich and poor nations (Brainard, 2005). With these gains in health and well-being, there is still a gap between rich and poor nations. This is probably related to conditions other than health factors that affect development (particularly the brain) in the very early years.

In looking at the determinants of inequalities in health in the United Kingdom, Donald Acheson and his committee in their report to the British government in 1998, (Acheson, 1998) concluded that, on the basis of the available evidence, there is no doubt that early child development has a long reach that affects physical and mental health and well-being in the later stages of life. This conclusion is in agreement with the conclusions from the historical analyses of Fogel (1994) and Drukker and Tassenaar (1997).

In a recent study on literacy in the United States (US Dept. of Education, 2002), the population with the lowest performance level in literacy had the poorest physical and mental health while those with the highest literacy competence had the fewest health problems. Again, each step up the gradient in literacy performance was associated with better health. Why is there a socioeconomic gradient and relationship between literacy performance and health status? There are many possible explanations but the development of the brain in the early years affects both literacy competence and health.

We now know that some regions of the developed world have fairly high performance on measures of health and literacy with fairly flat socioeconomic gradients (Marmot et al, 1995; Cavelaars, 1998; OECD, 2000). The evolution of new knowledge in the neurosciences and biological sciences has started to provide evidence about how the social environment gets under the skin to affect health, learning, behaviour and the competence of populations. It appears that the principle organ in the body that produces these gradients in health and well-being, behaviour, and literacy is the brain. Experience-based brain development in utero and the early years of life can set brain and biological pathways that affect health, competence and well-being (Barr, 2003).

EXPERIENCE-BASED BRAIN AND BIOLOGICAL DEVELOPMENT

The brain is the master organ that controls the main functions of all mammals (metabolism, reproduction, respiration, the cardiovascular system, the immune system, emotions, behaviour, response to stress and threats, learning and other functions) (Hyman, 1999; LeDoux, 2002a, 2002b; Sternberg, 2000; McEwen, 2002). Experience in the early period of life (in utero and the early years) has a major effect on the differentiation of nerve cells (neurons) in the brain for their different functions in the brain and the formation of connections (synapses) between neurons and biological pathways that affect health such as the immune system.

Experience through the sensing pathways in early life sets how the different parts of the brain and the biological pathways develop and function. This influences intelligence, literacy, behaviour, and physical and mental health (Cynader and Frost, 1999; Kandel et al, 1991, 2001; Nelson, 1999; Keating and Hertzman, 1999; Barr, 2003; Gluckman and Hanson, 2004).

The brain is composed of billions of neurons that have the same genetic coding, but as the brain develops through experience in early life, neurons in different parts of the brain through specific gene activation acquire functions that relate to specific sensing pathways such as vision, hearing, and touch (Hubel and Weisel, 1965; Rauschecker, 1999; Hensch, 2004; Klinke, 1999). It is the stimuli (experience) that these sensing neurons are exposed to in the critical, sensitive early periods of development (including in utero) that sets many of the brain's functions (Hyman, 1999; Knudsen, 2004; Seckl and Meaney, 2004; Gluckman and Hanson, 2004). The second biological point that is relevant to experience and brain development is how experience affects the formation of the connections (synapses) among neurons to establish pathways for the different hierarchies of the brain that govern or control our intellectual, emotional, psychological and physical responses to stimuli (Hebb, 1949; Sternberg, 2000; Nelson, 1999; Kandel, 2001; McEwen, 2002; LeDoux, 2002a; Knudsen, 2004; Fields, 2005).

In terms of the development of the brain, it is as important to understand how the various genes (DNA) are turned on and off. Genes can be deactivated more or less permanently by chemical processes that affect gene (DNA) function or the histone proteins around which the genes are coiled. This process is referred to as epigenetics. We now know that when a cell whose genes have been affected by epigenetics replicates, the epigenetic effect is often replicated with them. Epigenetics has languished in the shadow of the work of the human genome project but the importance of this field in brain development is leading to advocacy for a human epigenome project. All the neurons have the same gene information but through epigenetic processes, the function of genes in neurons in different parts of the brain is influenced.

Sensing Pathways: Study of the development of the part of the brain (occipital cortex) responsible for vision has helped understand the biological mechanisms whereby experience affects the differentiation and functions of the neurons in the brain.

Occasionally children are born with lens cataracts (preventing light stimulating the retina in the eye) with no stimulation of the optic nerve and the vision neurons in the occipital cortex following birth (Hubel and Wiesel, 1965). Surgeons felt that it was not wise to operate to remove such cataracts until the child was older because of the risk of surgery on small children. In contrast to adults with cataracts, late removal of the cataracts in these children did not lead to normal vision later in development (Cynader and Frost, 1999). It was simply too late for the visual neurons in the occipital cortex to respond appropriately and differentiate for the vision function. In adults who develop cataracts, the neurons in the occipital cortex have already become differentiated to function as vision neurons so removal of the cataracts leads to normal vision. David Hubel and Torstein Wiesel (1965) established in animal experiments that if signals did not pass from the retina to the brain during a critical period in early life, it was difficult for the neurons in the visual cortex to develop normal functions for vision later in development. Extensive experiments since then have shown that there appears to be a sensitive period for the development and wiring of the brain for vision that can be triggered once but only once (Hensch, 2004). This has led to the concept of critical periods for the development of at least some of the sensing systems, such as vision, sound and possibly touch. One of the important points is that the neurons that interpret the signals from the retina in the visual cortex and neurons associated with other sensing systems, such as sound, communicate with the rest of the brain, whose neuronal pathways and functions require inputs from the primary sensing pathways. This includes neuronal pathways and brain centres such as the amygdala, hypothalamus and hippocampus, involved in emotion, fear, behaviour, physical activity, literacy, memory, stress, and the body's host defense pathways.

The understanding of the development of the visual system has led to a considerable interest in the plasticity of the neurons and the neuron pathways throughout life and the concept of critical and sensitive periods during development in respect to the brain and the development of neural pathways (Rosenzweig and Bennett, 1996; Cynader and Frost, 1999; Hensch, 2004; Knudsen, 2004).

Hensch recently summarized the plasticity of neurons in the visual system in studies of the development of vision neurons in animals at different stages of development.

> In rodents and cats, plasticity is low at eye opening, peaks around four weeks of age, and declines over several weeks to months. In humans, amblyopia [a condition related to poor development of the visual system] is set by the age of eight. Notably, the critical period is not a simple, age-dependent maturational process but is rather a series of events itself controlled in a use-dependent manner. Animals reared in complete darkness from birth express a delayed onset [of the vision system] profile with plasticity persisting into adulthood. (Hensch, 2004)

The auditory pathway appears to also have a similar critical period. For example, children born with a dysfunctional cochlear system in the ear are deaf (Rauschecker, 1999; Klinke, 1999). This defect can be corrected to some extent by surgical

implantation of cochlear devices. If they are too late in doing this corrective surgery, the hearing restoration is poor (Rauschecker, 1999; O'Donoghue, 2000).

In reviewing the subject of critical and sensitive periods for the development of brain functions, such as birdsong and human speech, Doupe and Kuhl (1999) concluded:

> A critical period for any behaviour is defined as a specific phase of the life cycle of an organism in which there is enhanced sensitivity to experience, or to the absence of a particular experience. One of the most universally known and cited critical periods is that for human language acquisition. Songbirds also do not learn their vocalizations equally well at all phases of life.
>
> The term critical was initially coined in the context of imprinting on visual objects early in life, in which sensitivity to experience is short-lived and ends relatively abruptly. Many critical periods, however, including those for vocal learning, begin and end less abruptly and can be modulated by a variety of factors, so the term now preferred by many investigators is sensitive or impressionable period. Because critical period is such a commonly recognized term, we use these terms interchangeably, but with the caveat that this does not necessarily imply a rigidly regulated and complete loss of sensitivity to experience.

Another sensing pathway which may have a critical or very sensitive period which appears to affect a number of different neurological and biological pathways is touch. Touch (Tessier et al, 1998; Meaney, 2001a; Field, 2001; Charpak et al, 2005) has a very significant effect on the development of what is sometimes referred to as the stress, or the limbic-hypothalamus-pituitary-adrenal gland (LHPA) pathway. This pathway is connected to a number of pathways in the brain since it responds to emotion, fear, and threats, and influences diverse pathways, for example, the function of the cardiovascular system, behaviour, cognition, and the immune system (Sternberg, 2000; McEwen, 2002; LeDoux, 2002a).

In other work, it has become clear that for some parts of the brain there are sensitive periods for development (Knudsen, 2004) that are not as sharply defined as the critical periods. Knudsen has pointed out on the basis of the experimental evidence that, for most circuits, a host of cellular molecular changes contribute to the reduction in circuit plasticity after a sensitive period has ended. He makes the point that it is unlikely that these changes can be reversed later on in such a way that the capacity for plasticity that existed at the beginning of the sensitive period is reinstated. There are also parts of the brain that are capable of continuing renewal and development in normal circumstances (Gage, 2003). The one region that has been extensively studied in respect to renewal is that part of the brain associated with memory, the hippocampus. It appears to be capable of the synthesis of new neurons under appropriate conditions and stimulation and this is important for long-term memory. Renewal of neurons also appears to be true for parts of the hypothalamus and the amygdala as well as the olfactory neurons.

Synapses: The formation of connections (synapses) between neurons allows them to form pathways to communicate with each other in different parts of the brain and body (eg, neuromuscular control, immune system) (Kouichi et al, 1995; Kandel, 1991, 2001; LeDoux, 2002a; Sternberg, 2002; Fields, 2005). This is important for the function of the brain and other parts of the body. Hebb (1949) pointed out that understanding factors that influence synapse formation is key in understanding the plasticity and development of brain pathways and functions. In discussing this subject Rosenzweig and Bennett (1996) concluded:

> It should be noted that although the capacity for these plastic changes of the nervous system, and for learning, remain in older subjects, the cerebral effects of differential environmental experience develop somewhat more rapidly in younger than in older animals, and the magnitude of the effects is often larger in the younger animals. (Rosenzweig and Bennett, 1996)

Learning how to play golf, swim, play tennis or ski when you are young will lead to better performance than if you try to learn these sports in adult life. These skills are all dependent upon stimulation of the brain's sensing pathways and coordinated responses involving neuromuscular pathways. This, of course, is also true for language and understanding and behaviour. Knudsen (2004) has proposed that experience during a sensitive period modifies the brain circuits in fundamental ways causing neural pathways to become highly stable and therefore difficult to change.

Kandel and colleagues (Kandel, 1991, 2001) studying memory and learning in the snail Aplysia found that synapse formations for long-term memory differs from short-term memory in needing gene activation in the recipient neuron and the synthesis of new proteins by this neuron to enhance the synapse connection (Fields, 2005). Gene activation in the recipient neuron requires spaced but repeated stimulus at the synapse. The nature of this conditioning process is now fairly well understood but its application to the development of the pathways in the different parts of the brain is only now beginning to emerge. Fields (2005) has concluded:

> This transition from the present mental experience to an enduring memory has long fascinated neuroscientists. A person's name when you are first introduced is stored in short-term memory and may be gone within a few minutes. But some information, like your best friend's name, is converted into long-term memory and can persist a lifetime. The mechanism by which the brain preserves certain moments and allows others to fade has recently become clearer, but first neuroscientists had to resolve a central paradox.
>
> Both long- and short-term memories arise from the connections between neurons, and points of contact called synapses, where one neuron's signal-emitting extension, called an axon, meets any of an adjacent neuron's

> dozens of signal-receiving fingers, called dendrites. When a short-term memory is created, stimulation of the synapse is enough to temporarily "strengthen," or sensitize, it to subsequent signals. For a long-term memory, the synapse strengthening becomes permanent. Scientists have been aware since the 1960s, however, that this requires genes in the [recipient] neuron's nucleus to activate, initiating the production of proteins. (Fields, 2005)

The signaling neuron's axon interacts with the dendrite of the target cell. This stimulus causes, through the electrical pathways associated with stimulation, the target cells membranes to open up the calcium pores leading to an influx of calcium into the neuron, which activates CREB in the nucleus that activates the gene to produce what is called a synapse strengthening protein. (Fields, 2005) This diffuses to the site where the axon and dendrite are interacting, strengthening the connection. To get a strong connection, this stimulation has to be done repeatedly or else the strength of the connection will weaken and be lost. In terms of the function of the brain, this strengthening of synapses is dependent on the frequency of stimulation (a dose effect) in the brain.

Pavlov's experiments in dogs demonstrated the effects of repeated stimulation on brain function (Pavlov, 1927). He conditioned dogs to salivate on the signal of a bell by repeatedly giving the dogs meat and ringing the bell at the same time. After repeated exposure, the animals began to salivate with the ringing of the bell alone. To achieve this conditioning, the animals had to have repeated exposure to the bell ringing when the meat was given in order for the brain to develop pathways to respond with salivation to the bell alone. This can now be related to memory and the process of connecting and strengthening of synapses.

In careful analysis of the development of neurons and their connections, it was found that at birth, the synapses in the brain are not extensive but by the age of six they have become extensive reflecting the dynamic development of the brain in the early years (Huttenlocher and Dabholkar, 1997; Chugani, 1997, 1998). By the age of 14, the synapse connections are less intensive (Figure 3). If not used, the synapses are lost. Hebb referred to this process of the wiring and sculpting of the brain as "neurons that fire together wire together" (use it or lose it) (Hebb, 1949).

Gene Function: Gene activation, differentiation of neuron function, and synapse formation in the early years provides an explanation for some of the major behavioural problems we face in the mental health field. It has been recognized in monkeys that if they are heterozygous for the short serotonin transporter gene linked polymorphic region, they are at risk for decreased serotonergic function (serotonin is an important monoamine that influences, among other functions, the frontal brain and behaviour). If the infant animals with the short gene structure are separated from their mothers when they are young (lack of touch and other stimuli), they can develop poorly with abnormal limbic, hypothalamus pituitary gland adrenal gland (LHPA) pathways and poor serotonin function in respect to the prefrontal cortex and the risk of abnormal behaviour (depression) and alcohol addiction (Barr et al, 2004a; Bennett et al, 2002; Suomi, 2002).

The animals homozygous for the long gene structure for the serotonin transporter gene are resistant to adverse experience in early infant development (these are resilient animals).

The gene for the serotonin transporter comes in two lengths, a long and short. Each version is called an allele. The difference between the two lies not in the information for making the transporter itself (the "translation region") but in the portion of the gene that controls how well the translation of the gene coding is read, namely the "promoter region". In the studies in monkeys, it has been found that dysfunction in the serotonin pathway and the frontal brain is associated with hyperactivity of the LHPA pathway (Barr et al, 2004b).

Recent studies of the 1970 Dunedin birth cohort (Caspi et al, 2003) have shown that children who were raised in an adverse abusive environment with one or two copies of the short allele of the serotonin gene promoter polymorphism were at risk for depression in adult life. Those with the short gene structure brought up in a good early child development environment were not at risk. The subjects in adverse environments most at risk were those with the two short alleles. Subjects homozygous for the long allele serotonin transporter gene structure were resistant to the adverse effects of poor early child development (resilient children). The evidence about gene environment interactions involving the function of the serotonin transporter gene in relation to depression, and other behaviour problems such as behavioural inhibition has been recently confirmed by Kaufman et al (2004) and Fox et al (2005). Normally gene abnormalities are thought to be caused by genes producing a defective protein. However, since the DNA of both the short and long genes is normal in terms of mRNA coding for the transporter protein, some other mechanism related to gene activation or inhibition is involved. As discussed earlier, one biological pathway that affects gene function is epigenetics (Weaver et al, 2004; Harper, 2005; Reik et al, 2001). This is an example of how the social environment can get under the skin through the sensing pathways and influence biological pathways that can influence gene expression.

Another gene environment interaction which is relevant for complex psychiatric and behaviour disorders is the gene for monoamine oxidase A (MAOA) (Caspi, 2002; Yung-yu et al, 2004). This enzyme oxidases the monoamine neurotransmitters serotonin, dopamine, and norepinephrine. Humans with low MAOA activity tend to be associated with impulsive behaviour and conduct disorders. The MAOA gene, like the serotonin transporter gene, has a functional length polymorphism in the transcriptional control region for the gene. Caspi et al (2003) found a significant interaction between childhood maltreatment and low MAOA activity alleles. This was associated with increased risk for antisocial behaviour and violence. Individuals with high levels of MAOA expression did not show the same increase in conduct disorders as those with the low MAOA activity in relation to maltreatment in early childhood.

An important point that comes from this work is that it shows a non-genotype mechanism for transmitting patterns of behaviour for genetically vulnerable animals to the next generation. In the case of the serotonin transporter gene, a female with the short

promoter gene structure who has suffered from poor early infant development will have behaviour problems such as depression as a consequence of poor early development. She will then be at risk to poorly bring up her offspring, who could have a similar gene structure. These offspring will likely suffer from the same behavioural problems as the mother. (Barr et al, 2004b; Suomi, 2003)

The LHPA Pathway (Stress): This pathway has major effects on physical and mental health. In discussing the stress response, two terms are often used – the limbic system and the hypothalamus pituitary adrenal (HPA pathway or axis). The term limbic system was originally used to relate to the center for emotions. Since the concept was introduced, there is evidence that two structures in the limbic system of the brain (hippocampus and amygdala) play important roles in emotion, behaviour and memory and are inseparable from the stress response. The stress pathway is considered by many to involve the limbic system and includes the amygdala, the hypothalamus, the pituitary gland, the adrenal gland and the hippocampus (Gunnar and Vasquez, 2006; McEwen, 2002; LeDoux, 2002a). It also involves the autonomic nervous system (ANS) (McEwen, 2002; Sapolsky, 2003).

The hormones released by stressful stimuli work at different speeds. Epinephrine (adrenaline) works quickly while cortisol's (a glucocorticoid) action is slower. The amygdala plays a major role in the response to stress through the autonomic nervous system (epinephrine) and the cortico releasing hormone pathways. The hypothalamus stimulates the pituitary gland to produce ACTH which stimulates the adrenal gland to produce cortisol. One set of nerves projecting from the amygdala reaches parts of the mid-brain and brainstem which control the autonomic nervous system. It is this pathway that stimulates the autonomic nervous system to release epinephrine, which has a quick action and, among other actions, increases your heart rate, affects your breathing, and enhances your senses (Sapolsky, 2003). The activity reflects a form of implicit memory that does not require a conscious awareness. The slower acting stress pathway (hypothalamus, pituitary gland, adrenal gland) leads to the release of cortisol, which affects the function of cells in different parts of the body including the brain and has a longer lasting effect than epinephrine.

Cortisol can affect gene activation in different organs including the brain. Through these pathways, cortisol affects metabolic pathways and vulnerability to health problems such as type II diabetes. Cortisol has major effects on cognition and memory through its action on receptors in the brain particularly the hippocampus (Sapolsky, 2003). Increased cortisol levels in the blood interact with receptors in the hypothalamus and hippocampus to shut down the stimulus (cortical releasing hormone) from the hypothalamus to the pituitary and the release of ACTH, which stimulates the adrenal gland. In this dynamic system, emotional stimuli to the amygdala can override the normal regulation of the pathway leading to continuous stimulus for cortisol production from the adrenal gland (LeDoux, 2002a). This system can be thought of as similar to a thermostat in that its operation maintains an appropriate balance each day for normal allostasis (homeostasis) in the individual; that is, cortisol levels rise when you get up in the morning and return to

low levels at the end of the day if it has not been too stressful and the LHPA pathway functions normally. McEwen (2002) refers to this process as allostasis.

McEwen (2002) describes this dynamic regulation as the maintenance of stability through change (allostasis). The capacity of animals to make allostatic adjustments through change is necessary for survival. The biological processes set in motion are meant for short-term adaptations. If they persist too long, they can be damaging to the biological pathways influencing brain function and physical and mental health. The cost of allostasis is referred to as the allostatic load.

In studies of stress and development in rats, investigators have concluded that mothers' care during infancy programs stress responses in the offspring by modifying the neural systems in the LHPA axis (Caldji and Meaney, 1998; Caldji et al, 2000). The findings from research in animals indicate that early rearing conditions can permanently alter the set point for the control of the LHPA system (Meaney, 2001a, 2001b; Parent et al, 2005). This influences the expression of endocrine and biological responses to stress throughout life. This work has provided evidence about how early life events can affect the function of the LHPA system and subsequent behavioural and mood disorders in animals. (Plotsky et al, 2005; Caldji et al, 2000; Meaney, 2001a) In their work, they and others have concluded that conditions in early life can permanently alter gene expression (epigenetic effect). In this work investigators have found that adverse maternal behaviour can lead to poor protein synthesis from DNA because of epigenetic effects on the gene promoter functions (Weaver et al, 2004; Parent et al, 2005). Since methylation (an epigenetic pathway) of gene structures is difficult to reverse, this is a possible mechanism for the long-term environmental effects of maternal interaction with newborns on gene expression that can last throughout life. They and others have concluded that an epigenomic state of a gene can be established in early life as the consequence of the quality of maternal care (Weaver et al, 2004; Harper, 2005).

Although we do not know the precise pathways that are involved, touch in the early period of life seems to influence how the LHPA pathway functions in later life. In rats, it has been shown that if the mother neglects the pups by not intensely licking and grooming them at birth, they have a poorly regulated LHPA pathway, which can have major effects on brain function including cognition and behaviour in adult life. (Francis et al, 1999; Brake and Meaney, 2004; Caldji et al, 2003) In detailed studies of parts of the rat brain LHPA system, there is now evidence that neglect after birth (lack of touch) may lead to increased methylation of genes (epigenetics) in the LHPA system (Weaver et al, 2004). In this work, they have found that the offspring of mothers who show low licking of their pups will have a poorly regulated LHPA pathway. However, if these pups from a poorly nurturing mother are placed with a mother who has the high licking characteristics, the pups develop normally. Conversely, pups of high licking mothers raised by mothers that are low licking will tend to have the same defect as pups of low licking mothers.

Individuals working with rhesus macaque monkey colonies, such as Steve Suomi's group, have shown that the non-human primate model is very valuable for the study of

the gene environment interactions. Fortunately, in comparison to other laboratory animals, non-human primates have complex behaviours and social structures that approximate those present in human groups. In studies of rhesus monkeys growing up in the wild, approximately 10% show impulsive or inappropriate aggressive behaviour to stressful situations. They have found that these behaviour patterns emerge in early life and are remarkably stable from infancy to adulthood. Although these characteristics are clearly heritable, they are subject to major modifications by early experiences involving attachment relationships with their mothers. In these animals, there is a polymorphism in the serotonin transporter gene promoter (long and short alleles), which because of poor experience in early life, can affect gene function leading to extreme aggression and excessive alcohol consumption (Barr et al, 2004a) in the animals with the short allele. Animals homozygous for the long allele are resistant to the effects of poor infant development. Genetically vulnerable females who have poor early development will tend to poorly nurture their offspring (Barr et al, 2004a). Genetically vulnerable animals brought up in a good early environment for early monkey development do not show these behavioural problems (Suomi, 2003).

Animals with reduced activity of the genes controlling monoamines tend to have impaired LHPA axis to stress (Suomi, 2003). Maintaining a proper balance of this pathway is essential because both hyperactivity and hypoactivity affect what McEwen calls the allostatic state of humans and animals (McEwen, 2002). Changes in the allostatic state of load can accelerate brain aging and predispose individuals to stress related immunological, cardiovascular, behaviour and neuropsychiatric disorders.

The timing of the development of the LHPA system in rodents and primates appears to be different (Gunnar and Vazquez, 2006). Much of the development in rodents occurs in utero. In primates, much of the development is in the post-natal period. However, exposure to elevated levels of cortical releasing hormone (CRH) or cortisol prenatally influences the behaviour and physiological reactivity of the infant after birth. Thus, in humans, conditions in the prenatal period may affect the development of the LHPA pathway (Gunnar and Vazquez, 2006). The human studies show that poor maternal care of infants and toddlers is associated with increased cortisol levels. Offspring of depressed mothers tend to have higher blood cortisol levels.

The relationship between the LHPA system and the monoamine system in respect to behaviour has become an increasingly important area of study (Meijer and De Kloet, 1998; Meaney and Szyf, 2005; Manuck et al, 2005a). Monoamines function is influenced by the activity of the LHPA system. One aspect of this relationship is that serotonin has a direct effect on the hippocampus type II glucocorticoid receptors (cortisol) which are involved in the regulation of the LHPA axis activity.

Immune System: Another biological pathway that is influenced by the brain and the LHPA pathway is the immune system. In her recent book, Sternberg (2000) has outlined this pathway.

> New molecular and pharmacological tools have made it possible for us to identify the intricate network that exists between the immune system and the brain, [particularly the stress pathway] a network that allows the two systems to signal each other continuously and rapidly. Chemicals produced by immune cells signal the brain, and the brain in turn sends chemical signals to restrain the immune system…Disruption of this communication network in any way, whether inherited or through drugs, toxic substances or surgery, exacerbates the diseases that these systems guard against: infectious, inflammatory, autoimmune, and associated mood disorders.
>
> Cortisol has [from the stress pathway] a double-edged effect on the immune system. Too much of it suppresses immune function and makes us more vulnerable to infections. Yet in the short term, a burst of cortisol helps the immune system respond to an infection or injury. It sends the white blood cells, the body's main line of defense against injury and infection, to their battle stations…Cortisol also signals when the level of immune activity is adequate. It sends this message via the brain, which relays the information through the hypothalamus to the pituitary gland; the stress response is then adjusted accordingly. Cortisol's checks-and-balances effect is what makes it such a successful treatment for problems resulting from a hyperactive immune system, such as rashes or allergies, and for autoimmune conditions in which the immune system attacks the body's own healthy tissue. When we put cortisone cream on a rash or take steroids orally to fight inflammation, we are only supplementing what our own cortisol normally does.

Cytokines from the body's immune system can send signals to the brain in several ways. Ordinarily, a "blood-brain barrier" shields the central nervous system from potentially dangerous molecules in the bloodstream. During inflammation or illness, however, this barrier becomes more permeable, and cytokines may be carried across into the brain with nutrients from the blood. Some cytokines, on the other hand, readily pass through leaky areas in the blood-brain barrier at any time. But cytokines do not have to cross the blood-brain barrier to exert their effects. Cytokines can attach to their receptors in the lining of blood vessels in the brain and stimulate the release of secondary chemical signals in the brain tissue around the blood vessels (Sternberg, 2000).

Cytokines can also signal the brain via direct nerve routes, such as the vagus nerve, which innervates the heart, stomach, small intestine and other organs of the abdominal cavity (Sternberg, 2002). Sternberg (2002) makes the point that the brain body connections are crucial in the function of the immune system and the body's host defenses. This may be one of the reasons why stimulation of brain development in the early years is associated with better health in adult life.

In studies with rhesus monkeys, it was found that prolonged early social deprivation had an effect on mortality and a lifelong effect on cell-mediated immunity (Lewis et al, 2000).

THE NATURE NURTURE DEBATE

Genetics: The nature nurture debate has until recently led to a strong view that the major factor in human brain development was primarily genetically driven regardless of experience (Herrnstein and Murray, 1994; Ridley, 2004). As discussed in an earlier section of this paper, today we know that although genetics are important, experience and the environment in which individuals exist from the in utero period through to adult life has a significant effect on gene activation and expression (Suomi, 2003; Ridley, 2004; Meaney and Szyf, 2005; Jaffee et al, 2005). It is clear that in the early period of development when the biological systems for vision, sound, touch and other sensing pathways are developing, there has to be activation of genes in neurons to establish differentiation of neuron function. In terms of connections between neurons, there has to be repeated gene activation to form more permanent synaptic connections. Kandel has described this gene story for memory as "the molecular biology of memory storage: a dialogue between genes and synapses" (Kandel, 2001). It is clear that the formation of long-term memory involves experiences and gene expression.

As discussed in the section on the LHPA axis, the transcription of genes can be altered by changes in the chromatin structure induced by phosphorylation, acetylation, methylation and polyADP-ribosylation (Martinowich et al, 2003; Cohen-Armon et al, 2004; Meaney and Szyf, 2005). These experience based epigenetic effects influence the function of DNA (Harper, 2005; Weaver et al, 2004). The role for gene experience interaction in relation to brain function is brought out by studies of identical twins. For example, each identical twin does not have the same chance of having a major behavioural disorder as the other twin if they have different experiences in early life (Shonkoff and Phillips, 2000; Rutter, 2002; Sapolsky, 2003).

EARLY CHILD AND BRAIN DEVELOPMENT AND HEALTH

In the section examining the population gradients in health and inequalities in health, the concept was introduced that the development of the brain and biological pathways in the early years can affect physical and mental health in adult life. The health of populations as measured by death or sickness and socioeconomic status in developed countries is a gradient (Evans et al, 1994; Adler and Ostrove, 1999). In Western countries the largest number of individuals affected by the social determinants of health and well-being are in the middle class.

As discussed, conditions during pregnancy and early life influence the development of the brain and biological pathways that set risks for coronary heart disease, hypertension, type II diabetes, mental health problems and other conditions in adult life such as disorders of the immune system. The findings from a Swedish longitudinal study (Lundberg, 1993) show that children brought up in poor environments (neglect and abuse) during early child development have an increased risk in adult life for poor health. In the Swedish study, the risk for cardiovascular problems for adults who had been in very adverse early child circumstances in comparison to those who were in good environments for child development was 7 to 1. The risk for mental health problems, such as depression was 10 to 1. The data concerning depression in this study is compatible with what we are beginning to understand of how poor early child development can alter gene expression in relation to serotonin transport which con influence depression. The odds ratio for mortality for those brought up in the poorest environments was 1.9 compared to children brought up in good circumstances. These observations are compatible with our increased understanding of how social experience and brain development in the early years can affect pathways that affect emotions, behaviour, and vulnerability to depression as well as coronary artery disease.

Case et al (2002) using data from the United States from the National Health Interview Survey, the Panel Study of Income Dynamics, the Child Development Supplement, and the Third National Health and Nutrition Examination Survey, examined when the population socioeconomic gradients in health could be detected. They found that the socioeconomic gradients in health could be detected by age three and the steepness of the gradients increased as the population became older. This evidence is important since it shows that the gradient in health status in adults has its antecedent in early childhood. These findings are remarkably consistent with what we now know about the development of the brain in the early years and its effect on physical and mental health in later life. A key conclusion is that if we wish to improve equity in health, investment from a public health perspective in the early years of life (ages 0-3 years) is important. Also it is possible to spot signs and symptoms of poor early development and take steps to improve outcomes.

There have been a series of studies over the last 20 years showing that conditions in utero have a significant effect on physical and mental health problems throughout the life cycle Barker (1989, 1998) and Gluckman and Hanson (2004). These investigators have

concluded from their studies that men who grow slowly in utero remain biologically different to other men in adult life. They are more vulnerable to the effects of low socioeconomic status on the risk for coronary heart disease. In a recent analysis looking at early development and health, studies were carried out on individuals in South Australia born between 1975 and 1976 and men and women born in Preston, UK, from 1935 to 1943 and women born in East Hertfordshire, UK, between 1923 to 1930 (Phillips, 2000). They concluded that low birthweight is associated with raised cortisol concentrations (contributes to poor physical and mental health). Increased activity of the LHPA axis may be a factor in contributing to raised blood pressure in adult life. They also concluded from this study that this effect was not caused by confounding variables such as body weight, body fat distribution, smoking, or social class. Because the association was observed in young men and women in Adelaide, as well as older populations in the UK, it could mean that the factors that lead to low birthweight and adult hypercortisolemia affect men and women in young adult life as well as older life.

In their review of the fetal origin of health problems, Gluckman and Hanson (2004) provide substantial evidence that confirms the hypothesis put forward by Barker in his retrospective study of the British population. As well as their confirmation that the in utero environment can set risk for cardiovascular disease (coronary artery disease), they also provided evidence that the in utero environment can influence risk for type II diabetes as well as behaviour problems such as schizophrenia and possibly autism. In their work, they have concluded that the alteration in gene function by epigenetic processing will tend to stay with the individual throughout the life cycle.

Seckl (2004), in reviewing prenatal cortisol (glucocorticoids) and the long-term programming of biological pathways that influence disease, concluded, in respect to perinatal circumstances and bithweight, that this stage of development could program the function of LHPA pathway for later stages of life, with effects on blood pressure, type II diabetes, and hyperlipidemia.

In the case of atherosclerosis, the experiments in rabbits and monkeys (Kaplan et al, 1985; Kaplan et al, 1991; Nerem et al, 1980; Shively, 2000) show that when the stress pathway is overreactive, high cholesterol diets can produce extensive atherosclerosis in rabbits and monkeys and arterial thrombosis in monkeys. In these studies, animals that were not stressed, although they had the same cholesterol level as the stressed animals, did not develop severe atherosclerosis and arterial thrombosis. There appears to be an effect of the stress related biological pathways on the endothelial lining of the arteries leading to alteration or vessel injury in major arteries. Arterial vessel injury plus high cholesterol levels can lead to extensive atherosclerosis (Moore, 1989).

Manuck (2005b) has recently reported that there is a socioeconomic gradient in serotonin responsivity as a function of the allelic variation in the serotonin transporter gene linked polymorphic region. Since the risk for cardiovascular disease increases with chronic stress and is related to the socioeconomic status of individuals, they have studied the relationship of cardiovascular disease to variations in brain function (influenced by the stress pathway). They found a socioeconomic gradient in serotonin function that was

related to individuals having the short alleles but not for individuals with the long alleles for the serotonin transporter gene. In this work, they found that disregulated serotonergic function correlated with cardiovascular risk factors such as smoking, blood pressure, type II diabetes. These relationships raised the question as to whether some of the cardiovascular risk factors are, in effect, markers of behaviour related to brain development and that the stress pathways may be a factor in causing endothelial alteration or injury in major arteries.

A behavioural disorder that is of some significance in societies is attention-deficit hyperactivity disorder (ADHD), which affects 8-12% of children worldwide. Studies have shown that this condition in children can be associated with psychiatric and substance abuse disorders (Cantwell, 1996; 1997; Teicher, 2002; Nadder et al. 2002; Biederman and Faraone, 2005). This appears to be a condition caused by the interaction between the environment and genetic vulnerability. Pregnancy and delivery complications, such as toxemia or eclampsia, prematurity and exposure to alcohol and cigarettes during pregnancy, appear to be environmental factors that can alter the brain development in early life leading to this behavioural disorder (Biederman and Faraone, 2005).

Dysfunction of the LHPA axis with lower levels of cortico releasing hormone secretion, can, in part because of low plasma cortisol levels, result in a hyperactive immune system. Patients with a mood disorder called atypical depression also have a blunted stress response and impaired CRH secretion, which leads to lethargy, fatigue, and increased eating that often results in weight gain. Patients with other illnesses characterized with lethargy and fatigue such as the chronic fatigue syndrome, fibromyalgia, and seasonal affective disorder (SAD), exhibit features of both depression and a hyperactive immune system (Sternberg, 2000; McEwen, 2002) associated with low cortisol levels.

There is also evidence from animal and human studies that poor development in the early years can lead to increased risk for alcohol or drug addiction. As discussed in the section on brain development, studies with rhesus macaque monkeys or rats show that inadequate touch stimulation in the early period of development influences the risk for both behaviour and alcohol addiction problems in later life (Barr et al, 2004a; Weaver et al, 2004). In studies of the Kaiser Permanente program in California (Felitti et al, 1998), it was found that individuals who had been exposed to child neglect and abuse when young were at high risk for drug and alcohol addiction in adult life.

As discussed in the section on the stress pathway, experiments with monkeys have provided further evidence about the gene environment interactions and health problems (Suomi, 2003). Rhesus macaque monkeys were grouped into genetically vulnerable and resistant strains. The vulnerable strain, if not raised by a nurturing mother, are at risk of an over stimulated stress system with exaggerated cortisol response and poor return to resting levels. As adults they show increased anxiety and depressive behaviour, excessive alcohol consumption when given access to it, impulse aggression and violent behaviour and high circulating sterol levels. These animals show high sterol levels in response to stress, low brain serotonin levels and a disrupted circadian rhythm for

cortisol. When offspring from the genetically vulnerable poor mothers were taken and reared by highly nurturant mothers, the high risk infants showed normal development and became secure in their exploratory patterns (Suomi, 1999). In a recent study, Maestripieri (2005) has reported how early experience affects the intergenerational transmission of infant abuse in rhesus monkeys. He has concluded, in keeping with the work of Suomi et al (2002, 2003), that the intergenerational transmission of infant abuse in rhesus monkeys is largely the result of infant experience in early life affecting gene function.

The evidence that comes from studies of the social determinants of health and well-being in humans, monkeys, rats and other mammals show that the effect of the social environment on brain development and function in early life is a factor contributing to health problems, (physical and mental), throughout life.

In reviewing all of the available evidence about early childhood and health, Sir Donald Acheson's Commission on Inequalities in Health in Great Britain (Acheson, 1998) concluded,

> Follow up through life of successive samples of birth has pointed to the crucial influence of early life on subsequent mental and physical health and development.

EARLY CHILD AND BRAIN DEVELOPMENT AND BEHAVIOUR

As discussed in the health section, how the brain develops in the early stages of life affects behaviour later in life. In humans we tend to have two categories of behaviour. One is medical such as schizophrenia and depression (psychiatry). The other is a psychological classification such as antisocial behaviour (conduct disorders), anxiety etc. They are all manifestations of brain function involving many shared components of the brain pathways and monoamines such as serotonin, dopamine and norepinephrine.

Attention-deficit hyperactivity disorder (ADHD) is a product of interaction between the environment and genetic vulnerability (Biederman and Faraone, 2005). Environmental factors that contribute to ADHD in vulnerable individuals include pregnancy and delivery complications, prematurity, and a dysfunctional family environment (Offord et al, 1992; Biederman et al, 2002, Biederman and Faraone, 2005). It is perhaps not surprising since the brain pathways involved in ADHD are also involved in other forms of behaviour, that this condition is associated with other behavioural problems (comorbidity) (Nadder et al. 2002; Biederman and Faraone, 2005). It is interesting that amongst the comorbidity problems associated with ADHD are psychiatric disorders and substance abuse (Biederman and Faraone, 2005). Although the reasons for this linkage are not clear, it is probably related to the various brain pathways that influence behaviour which are part of common biological pathways and the frontal brain. Nadder et al (2002) concluded that the co-morbidity was governed by environmental influences that affect a shared genetic liability through gene environment correlations or interactions. It is interesting that ADHD can put adults at risk for personality disorders at all ages. This behaviour is associated with functional disorders such as school dysfunction, family conflict, poor occupational performance and antisocial behaviour (Biederman and Faraone, 2005). Among the genetic factors considered to contribute to ADHD are the dopamine transporter gene, the monoamine oxidase gene, serotonin receptor genes and the serotonin transporter gene (Faraone et al, 2005). Further understanding of factors contributing to ADHD will need a better understanding of gene environment interactions in respect to the various nerve pathways and the effect of environmental stimulation on gene function.

Tremblay (1999, 2004, 2005) has shown that at two years of age most children show antisocial behaviour ("the terrible twos") that usually comes under control before the children reach school age if the children are in good early child development environments. Children brought up in neglectful abusive early child development conditions will show significant antisocial behaviour at the time of entering the school system. In a study of antisocial behaviour (aggression) in children entering the Montreal school system, Tremblay found about 14% of children show little physical aggression and about 53% show moderate aggression that gradually comes under control. About 32% showed high levels of aggression at the time of school entry with some improvement in control as they become teenagers. About 4% of the children did not improve and were considered chronic. Many of the teenage males in the chronic group ended up in the criminal justice system. As discussed in the previous section, studies

with animals (rats and monkeys) show that poor environments for early development can lead to poor regulation of the LHPA system with negative effects of cortisol and other hormones and neurotransmitters on brain function and behaviour. In Tremblay's studies, only about 30% of children entering the school system with high or chronic antisocial behaviour get a high school diploma. There is clearly an effect of the pathways affecting behaviour and learning.

Martin Teicher (2002, 2003) in his studies of brain development and function in relation to neglect, physical or sexual abuse, and family violence, found using today's imaging methods(fMRI) to study brain function, that adverse early child development environments led to changes in brain structure. He concluded that severe stress (the LHPA pathway) leaves an indelible effect on brain structure and function. He found the aftermath in adult life could appear as depression, anxiety, post-traumatic stress, aggression, impulsiveness, delinquency, hyperactivity or substance abuse. As discussed, a Kaiser Permanente health care program study found a strong correlation with child neglect and abuse and addiction to alcohol and drugs in adult life (Felitti et al, 1998; Dube and Felitti, 2003). Teicher has suggested that the effects of early stress that alter the neurological pathways in development may prepare the adult brain to help individuals survive and reproduce in a dangerous world. Parent and colleagues (2005) have also concluded that transmission of individual differences in stress and behaviour to offspring could be adaptive with respect to survival in adult life in a chaotic environment.

An interesting longitudinal study of the relationship between early child development for language and intelligence in males was carried out in Sweden by Stattin and Klackenberg-Larsson (1993). They found significant correlations with registered teenage criminality and language and intelligence development at 6, 18, and 24 months of age. Although there are many explanations for this relationship, it is difficult to ignore the evidence that the degree of verbal exposure by reading and talking in early development (infants, toddlers and young children) has a significant effect on their verbal skills and language at later stages of development (Hart and Risley, 1995). Also it is difficult to talk to or read to an infant or toddler without holding it (touch). As described in the section on brain development, touch is a critical factor influencing the development of the LHPA pathway, which, if it is dysfunctional, can influence behaviour, including antisocial behaviour, in later life. The experience of multiple sensing pathways in early life can affect multiple functions such as language, intelligence and behaviour in later stages of life.

In the Canadian National Longitudinal Survey of Children and Youth (NLSCY), Willms (1999, 2002b; McCain and Mustard, 1999) found that in Canada about 35% of the age 4 to 6 children in the poorest socioeconomic class had poor early child development and were vulnerable to cognition and behaviour problems. About 12% of the children in the upper socioeconomic class were vulnerable at the time of school entry. In this study, the relationship to social and economic factors and vulnerability in early childhood was a gradient. From this work it was concluded that the largest number of vulnerable children at school entry are in the middle class. In Willms' studies, they examined the relationship between cognition and behaviour and conditions for child development. It

was found that if the parents read to the children when they were young and if there was good local support for the families, there was no socioeconomic gradient for cognition or behaviour in the age 4 to 6 group (Willms, 2002b).

This evidence is compatible with the concept that vulnerability in gene structure combined with a poor environment for early child development can lead to significant behaviour and language problems in later life.

EARLY CHILD AND BRAIN DEVELOPMENT AND LITERACY

Early child and brain development has a major effect on language and literacy in later stages of development.

The biological pathways that are involved in the development of language and literacy are only partially understood (Shonkoff and Phillips, 2000; Pugh et al, 2001; Shaywitz et al, 2004). It is clear that what is picked up through the vision and the hearing sensing pathways has to be linked to parts of the brain such as Broca's and Wernicke's areas as well as being linked to the sections of the brain involved in the ability to talk and write (Shaywitz et al, 1998). In terms of reading, investigators now refer to the parietal temporal region, the inferior frontal gyrus and temporal region. We know that the sounds that an infant is exposed to when very young influence how the auditory neurons develop and function (Kuhl et al, 1992, 1993a, 1993b). For example, infants exposed to two languages (for example, Japanese and English) in the first seven to eight months of life will have little difficulty in setting the base for easily mastering the two languages and they will not have an accent (Mechelli, 2004; Maye et al, 2002; Kuhl, 1992, 1993a). Individuals who develop understanding of two languages early in life have a larger left hemisphere of the brain than individuals with monolingual backgrounds. Proficiency in the second language is directly related to the size of this part of the brain. The increased gray matter density in the left inferior parietal region was also found to be related to the age of acquisition of the second language (Mechelli, 2004). Since acquisition of a second language is best achieved in very early life, this indicates that there is a sensitive period for brain development and function for optimum language acquisition, literacy and the associated understanding. It is interesting that the other findings from these studies are that individuals who acquire a second language very early in life find it easier to learn third and fourth languages later in life. It would appear that the neurons in the auditory cortex that respond to sound develop a sensitivity to the sounds of different languages in early life that make it easier to differentiate the sounds and develop the neurological pathways necessary for capability with multiple languages. Kuhl (1993b) has concluded that the speech system remains most plastic to experience (sound) for a short period of time in early life.

The work of Huttenlocher et al (1991) and Hart and Risley (1995, 1999) (Kuhl, 1992, 1993b; Gopnik et al, 1999) has shown the extent of language exposure to children in the early years has a significant effect on the verbal skills of children at age three. The difference in verbal skills at age three among the different socioeconomic groups in the Hart and Risley study still held in respect to language capability and understanding at age nine. This observation is compatible with the evidence that the most sensitive period for brain development in respect to language capability is in the early years. Kuhl (1993b) demonstrated that after the first 12 months of life the ability to discriminate phonemes in languages to which they are not exposed, greatly diminishes.

Knudsen (2004) in his review of critical and sensitive periods for brain development makes the point that the different neural circuits involved in language development and

understanding are a hierarchy. Some may have a critical or sensitive period that must develop before the other pathways can form. He concludes that the brain circuits involved in phonetic analysis and grammar and syntax also have a sensitive period. This evidence is compatible with the concept that trajectories for language and literacy performance tend to be set in early life. The data from longitudinal studies and the few randomized early intervention programs indicate the early years are when the brain is most plastic for the development of verbal skills and language.

Both humans and songbirds learn their complex vocalizations early in life showing a strong dependence on hearing the adults (Doupe and Kuhl, 1999). Humans and songbirds have evolved a complex hierarchy of specialized forebrain areas in which motor and auditory centers interact closely. Dyslexics show a slow communication between parietal temporal region, the inferior frontal gyrus and temporal region (Broca's and Wernicke's areas) (Shaywitz et al, 1998, 2002). They also show impairments in naming pictures of subjects in addition to the difficulties with reading (McCrory et al, 2005). In recent studies, reduced activation in the left occipital temporal area was found for both word reading and picture naming.

Many studies show that children who develop poor verbal skills during the first three years of life will do poorly in language and literacy in the school system (Hart and Risley, 1995; Huttenlocher, 1991; Stattin and Klackenberg-Larsson, 1993).

Recent studies of children with dyslexia who have been through a program of language development based on phonics, indicates that there may be considerable plasticity in the neural circuits connecting the different parts of the brain involved in language and words. With this strategy, the brains of the dyslexic children (6 or older) exposed to phonics programs, established, as assessed by fMRI, the development of normal neurological pathways for both word reading and picture naming within eight months (Shaywitz et al, 2004; Price and Mechelli, 2005). The research tool used to assess this was fMRI, which measures the function of the different parts of the brain. The children as well as showing the normal activation of the centres for speech, reading, and language, no longer had difficulty in reading. These results indicate that many of the centres and neurological pathways for reading and speech are still to some extent plastic in later stages of development.

The Organisation for Economic Co-operation and Development (OECD), and Statistics Canada, and the United States Department of Education have been conducting population-based assessments of prose, document, and quantitative literacy.

Since the development of the brain in the early years affects neurological and biological pathways that affect health (physical and mental), learning, and behaviour throughout the life cycle, it is interesting that the OECD studies on adult populations' literacy in developed countries show a strong correlation between literacy performance and life expectancy (Figure 4).

In these population assessments of adult literacy (prose, document, and quantitative), the OECD and U.S. Department of Education use a scale of 1 (low) to 5 (high).

Each level can be described in terms of what individuals were able to do. For example, persons proficient at Level 4/5 on the prose scale are capable of making medium to high level text-based inferences by integrating or contrasting abstract pieces of information in relatively lengthy texts that contain several to many distractors.

At Level 3 on the prose scale, persons can make low-level text-based inferences by locating several pieces of information from a few to a number of different sentences or paragraphs, and integrating or contrasting information across sections of text that contain few to several distractors. This level is deemed as a minimum for persons to understand and use information contained in the increasingly difficult texts and tasks that characterize the emerging knowledge-based society and the information economy.

Those scoring at Level 2 on the prose scale are capable of making low-level text-based inferences by locating one or more pieces of information, and integrating or contrasting two or more pieces of information across sections of text that contain some distractors. Thus, persons at this level may not be able to consistently understand more difficult texts and tasks that are increasingly prevalent in modern societies.

Proficiency at Level 1 indicates that persons may be able to locate one piece of information that is identical or synonymous with the information given in a directive but in general they have difficulty making low-level text-based inferences.

In the assessment of literacy in the developed world and Latin America, the literacy levels of the population plotted against their parents' level of education are gradients (those low on this SES measure have poorest performance). It is interesting that Latin American countries such as Chile performed less well in contrast to developed countries like Canada, The Netherlands, and Sweden (Figure 5). In the recent studies, it was found that between 42% and 48% of individuals (ages 16 to 65) in Canada and the United States performed poorly on the literacy assessments, (Levels of 1 and 2). In Latin American countries like Chile more than 80% of the population was at Levels 1 and 2. In Canada and the United States, between 15-20% of the population scored at Levels 4 and 5 (high). In contrast, countries like Sweden had 34% at Levels 4 and 5, while in countries like Chile, less than 3% were at Levels 4 and 5 (Table 1).

Figure 6 shows the results for the adult literacy assessment in the United States carried out by the Department of Education. About 50% of the adult population is at Levels 1 and 2 and only about 5% are at Level 5 in this study. In the American study they assessed prose, document and quantitative literacy.

In the study of the U.S. population, 50% of the population at Level 1 had (U.S. Dept of Education, 2002) physical and mental health problems (Figure 7). Those with the highest literacy skills had far fewer physical and mental health problems. The health problems are a gradient when plotted against the population's literacy competence. Each step

down the scale of literacy capability, the worse the health status of the population. An interesting question is, why is there a relationship between literacy competence and health status? Is this related to experience-brain development in early childhood and its effects on brain pathways that affect health as well as literacy competence?

It could be argued that because Canada and the United States have a mixed immigrant population in contrast to the more homogeneous Scandinavian population, the difference in literacy performance is due to the heterogeneity of populations in Canada and the United States. The UNESCO studies of Latin American countries (Casassus, 1998), however, show that heterogeneity of populations is not a barrier to a country having a high literacy performance. Cuba's performance in the literacy assessment for children is better than the other Latin American countries (Willms, 2002a; Carnoy and Marshall, 2004). The government of Cuba introduced health and other programs for mothers and young children more than 30 years ago. They focused on health and child development. Today Cuba's performance on the literacy assessments is better than the other Latin American countries and the life expectancy is better than almost all other Latin American countries. In the grade 3 tests in language and mathematics, the mean value for the Cubans was two standard deviations better than the mean value for other Latin American countries (Casassus, 1998). Another interesting feature of the Cuban data is that they had only one-quarter the number of fights in the school system in contrast to the data from the schools in the other Latin American countries (Carnoy and Marshall, 2004). The Cuban data is compatible with the concept that a good early child development program can improve outcomes for a mixed population (African, Spanish, Indian). Cuba's early child development initiatives begin with pregnancy and continue until the children enter the school system. There are two components to the program:

1. A center-based full day program; and,
2. A home visiting program which does include a part time center-based initiative.

The staff are well educated and these programs are universal (Coe and McConnell, 2004; Gasperini, 1999).

There has been some criticism that the data from Cuba may not accurately reflect the characteristics of the population because of biased tests and sampling errors. However, one of my colleagues involved in the study has no reservation that the data reflects the characteristics of the Cuban population studied (Willms, personal communication, 2005). Also, since health (life expectancy) (United Nations Human Development Report 2005) and literacy show a strong correlation, the better life expectancy of the Cubans correlates with their literacy performance.

In developed countries there is a relationship between poverty and literacy. In the U.S. literacy study, about 50% of the population at Level 1 were in poverty and only 5% of the population at Level 5 were in poverty (Figure 8). In the U.S. population, the relationship between poverty and literacy is a gradient. In the OECD studies, there was a strong correlation between equity in literacy and equity in incomes. Thus, there is little doubt that to reduce poverty in countries there has to be a substantial increase in our investment in early child development to improve the competence and quality of all members of a society.

The fact that some countries show high performance and fairly flat socioeconomic gradients while others do not, indicates that the performance can be improved in countries with steep population socioeconomic gradients. All the countries with fairly flat gradients and high performance in literacy have quality, universal programs for early child development (OECD, 2001). At present, there is very limited evidence that special education programs, once children enter the school system, improve their literacy performance to the same extent as that produced by a good preschool program (Mervis, 2004). To achieve high population performance and equity in literacy, it appears that societies will have to make a larger investment in early child development programs.

One of the potential problems in today's societies is the effect of modern technology, such as computers and television, on brain and child development. In one recent study, the investigator concluded that television viewing in childhood and adolescence is associated with poor educational achievement by 26 years of age (Hancox et al, 2005). Based on the results from the New Zealand 1970 birth cohort study, television may have adverse long lasting consequences for educational achievement and subsequent socioeconomic status and well-being. In this longitudinal study, they found there was a gradient in this population for post school qualifications in relation to the number of hours of television viewing in the child and adolescent period. Zimmerman et al (2005) using data drawn from the National Longitudinal Survey of Youth (1979), sponsored by the U.S. Department of Labor, found that there were modest adverse effects of television viewing before age 3 and the subsequent cognitive development of the children. One conclusion from this work is that as children spend more time watching television, they spend less time in other activities such as reading and talking with caregivers and playing with other children, and play, that is necessary to stimulate multiple pathways in brain development. One particularly adverse effect of television in the early years may be actually less contact with the caregiver (lack of touch).

In all the population-based studies of health, behaviour, and literacy, the outcome measures are a gradient when plotted against the socioeconomic status of the population studied. About 40% of the Canadian population in the lower socioeconomic groups perform poorly in health and literacy (Manitoba, 2004; OECD, 2000). Only about 22% perform at Levels 4 and 5 in the literacy assessment. About 75% of the Canadian population can be classified as middle class. Thus, the largest number of individuals affected by the social environment factors influencing health, learning, and behaviour are in the middle class (McCain and Mustard, 1999). Whatever in the social environment affects health, learning, and behaviour, it affects all social classes; obviously, more in the lower social class and fewer in the top social class are affected. However, because of the size of the middle class in developed countries, the largest number of individuals that are affected by poor early child development are in the middle class. Thus, any program to improve the competence and well-being of populations should be available for all families with young children.

Willms, in his paper about raising and leveling the learning bar (2004), has made the point that such initiatives will have the greatest effect on children in the lowest

socioeconomic position but it will also affect children in all social classes, thus improving the quality of all social classes creating greater equity in literacy throughout the country and flatten population gradients (Willms, 2002b, 2004).

PROGRAMS TO ENHANCE EARLY CHILD DEVELOPMENT (ECD)

The inequities in literacy and understanding in developed and developing countries will make it difficult for all societies to understand the challenges we face in an increasingly globalized world with its population, resource and environment problems and continue to improve our experiments in civilizations.

The weight of the evidence discussed shows that the quality of experience in early life (in utero, infancy, toddler, early childhood) affects learning in the school system as well as learning, behaviour and vulnerability for physical and mental health problems in adult life. There are four sources of information that are relevant to discussion of the effectiveness in society of initiatives to enhance early child development and improve the competence and quality of populations. The data come from birth cohort longitudinal studies, cross sectional studies, observational studies, and randomized controlled trials. In assessing the results from these studies, it is important to assess how consistent the results are with the emerging knowledge from the neurosciences and biological sciences in respect to brain and biological development in early child development and trajectories in health, behaviour, and learning.

One set of observational data on early child development and experience comes from studies of children put into orphanages of varying quality early in their life. Frank and Earls (1996) in their review concluded that infants and young children are vulnerable to the medical and psychosocial hazards and neglect associated with institutional care in most orphanages. They also found that the negative effects of the early years in the orphanages were not reduced later in adult life to a tolerable level even with massive expenditures. Most orphanages put young children at increased risk for infection, poor language development and behaviour problems and many of these children became psychiatrically impaired and economically deprived adults. In their book, *Liars, lovers and other heroes*, Quartz and Sejnowski (2002) examined what is happening in China where, because of the one child policy and preference for males, many baby girls are put into orphanages. In many places, these female infants and toddlers are placed in long rows of cribs with three or four adults looking after 50. As the toddlers become young children, they are placed in buildings behind the main building known as the “dying rooms”. They describe the horror of this deprivation leading to children withdrawn into their shells, their bodies stiff and motionless, starving not only for food but human contact. They point out that in these dying rooms the abuse is passive. Children are simply neglected and denied human contact. How our societies handle the increasing number of orphans in Sub-Saharan Africa as a consequence of the AIDS epidemic will test how well we can apply our new understanding of early child development to improve the chances for orphan children in countries with major health, family, and socioeconomic problems.

An informative orphanage observational study is the fate of infants and toddlers adopted from the Romanian orphanages following the collapse of the Communist government. In a study of Romanian orphanage children adopted into middle class British homes, Rutter

(2004) examined the development of these children compared with 52 non-deprived U.K. born children placed into adopting families before the age of six months. There was a strong relationship between cognitive development and the age at which the Romanian children were adopted into British homes. The earlier the adoption, the better the outcome. Although there was some recovery for all children after adoption into British middle class homes, substantial deficits in development persisted for many of the children adopted after many months in the orphanages. They concluded that there was some form of early biological programming or neural damage of the vulnerable children stemming from the effect of institutional deprivation. This effect could not be substantially changed by the quality care of the middle class families that adopted them.

These findings are in agreement with those of Ames (1997) and Lucy Le Mare (2005) and colleagues in their study of Romanian orphans adopted into middle class Canadian homes in British Columbia. They compared the children adopted within the first four months after birth with those who had spent more than eight months in the Romanian orphanages. Both groups were compared with Canadian born middle class children raised within the birth family structure. When the children reached ten years of age, they found that the group that spent more than eight months in an orphanage (late adoptees) had lower IQ's than the children adopted early and the Canadian children of British Columbia families. This finding is in keeping with the finding that IQ is influenced by the quality of early child development (Wickelgren, 1999; Klebanov, 1998). The late adoptees had lower school achievement scores, more attention deficit disorders and more behavioural problems. It is interesting that parents who adopted the children who had been eight months or more in a Romanian orphanage reported far greater parenting stress than the parents who had adopted Romanian children soon after birth. In terms of attention deficit hyperactivity disorder, 34% of the late adoptees had a clinical diagnosis, while only 3% from the British Columbia group, and 9% of the early adoptees had this problem. All of these observational studies are compatible with the evidence that the quality of support and care given to infants in the early months has a significant effect on brain development and behaviour and learning later in life. The results also show that while you can help the late adoptees develop, they do not reach the same level of performance as those adopted early. This evidence is also in keeping with the biological data that there are critical and sensitive periods in early life for the development of the brain and related biological pathways that set functions that are difficult to change later in life.

In Toronto, Mary Gordon (2002) in collaboration with the Toronto District School Board, set up parenting and family literacy centres in the primary schools involving pregnant mothers, infants, toddlers, young children and their parents or grandparents. Very skilled leaders led this program in the primary schools, and the parents, usually the mothers and sometimes the grandparents, were involved in the initiatives with the children at the centres. It was a clever strategy to help parents learn parenting by being in a positive social environment. This was a voluntary program but there was considerable uptake by the families with young children in the communities around the schools. The kindergarten teachers found that about 50% of the children not in the program showed poor literacy and numeracy development in comparison to only 7% to 14% of the

children in the parenting program. In an assessment of the outcome for the two groups of children using the Early Development Instrument (EDI) (Janus and Offord, 2000), 51% of the children not in the program had low scores while only 30% of the children in the parenting program had low scores at the time of school entry.

In a more recent initiative designed to teach empathy to children in the school system, Gordon has created a Roots of Empathy program (Gordon, 2005). The short-term goal of this program is to foster the development of empathy in children in the school system. The initial research shows that children in the Roots of Empathy program exhibit increased emotional understanding and pro-social behaviours and a significant decrease in aggressive behaviours. The teachers rated the children taking part in the Roots of Empathy program as less aggressive at the end of the school year. In Tremblay's studies discussed in the section on behaviour, most children coming into the Montreal school system manifesting antisocial behaviour show improvement in their behaviour during their time in the school system. The ones who exhibit high levels of antisocial behaviour when they enter the school system show a slow improvement. It is possible that the Roots of Empathy program is influencing the speed with which the children in the schools acquire a more pro-social behaviour pattern. It may be that those who show chronic antisocial behaviour will not change. In considering the results, it is important to remember that in the Romanian orphanage study the late adoptees placed in good middle class homes improved but they still had significant behavioural problems at the age of ten in contrast to the early adoptees.

An interesting study of human development in the early years and longevity has come from the studies of the Catholic nuns who were sisters of the Notre Dame religious group in Dallas, Texas (Riley, 2005; Danner et al, 2001). It was found that positive emotions in early life were associated with a decreased risk of mortality in adult life. In a subsequent study, they found early life idea identity (a measure of cognitive function) was associated with the level of cognitive skills in later life. Low cognitive skills in early life was associated at the time of death with lower brain weight, a higher degree of cerebral atrophy, and brain changes compatible with the neuropathologic criteria for Alzheimer's Disease.

The findings from longitudinal studies of birth cohorts have increasingly provided evidence about how the conditions of early life can affect health and development over the life course. Wadsworth (1991) and colleagues in a detailed study of the 1946 British birth cohort have provided evidence about how conditions in early life can set risks for both physical and mental health problems in adult life. Power, Manor and Fox (1991) in their studies of the 1958 British birth cohort explored the causes of inequalities in health. In the initial work, they concluded that circumstances prevailing at each stage of child and adolescent development were relevant to the health differences among adults. In more recent work (Power et al, 1997, Power and Hertzman, 1997, Power et al, 1999), they have presented further evidence that the manner in which brain and biological pathways develop in early life influence adult disease.

In a study of the 1970 New Zealand birth cohort Poulton et al (2002) came to the same conclusion that poor socioeconomic circumstances for early child development have long lasting negative influences on adult health. They came to the conclusion that the socioeconomic gradient in health in adults emerges in childhood. This is comparable with Fogel's conclusion that improvement in early child development following the Industrial Revolution was a key factor in the health improvement in Western countries.

Jefferis and colleagues (2002) have examined the relationship between birthweight, childhood socioeconomic environment, and cognitive development in the 1958 British birth cohort. They found that the postnatal environment had an overwhelming influence on cognitive function. Birthweight had a weaker but independent association. Low birthweight children in the upper social class had better mathematics results than the low birthweight children in the lower social classes at age seven and eleven. Furthermore, the school system did not change the performance for the low birthweight children who were in the low social class.

Power and Hertzman (2006) are completing their studies of the biological pathways and development in 1958 British birth cohort at age 45. They have found the cortisol secretion patterns at age 45 are correlated with conditions influencing early child development. Cortisol secretion at age 45 is associated with the mathematical skills at 7 to 16 years of age reported in their earlier paper (Jefferis et al, 2002). This illustrates that early brain development affects the stress pathways (LHPA) and that it is involved in learning and cognition (mathematics) at this time.

In the examination of the effect of child parent centres in the Chicago Longitudinal Study (Reynolds et al, 2004), it was found that the child parent centres located in or proximal to public elementary schools for children from ages 3 to 9 produced differences in child development when compared with children not in the program. A key finding was that there was significantly higher educational attainment and lower rates of juvenile arrest. The results from this operational research project are compatible with the findings concerning experience-based brain development in the early years. Although this initiative enhanced early child development, the gains were probably less than what would have been achieved if the families with young children had been brought into center-based early child development programs involving parents at an earlier age.

The 1970 longitudinal British birth cohort studies clearly show that young children in center-based preschool programs do better in school than children who are not in these programs (Egerton and Bynner, 2001; Osborn and Milbank, 1987). In these studies they show quite conclusively that preschool programs and parenting practices were important predictors of the mobility of children from all social classes in the school system. In further analysis of the 1970 British birth cohort, Feinstein (2003) found that the development score at 22 months of age predicted educational qualifications at age 26. The overall conclusion from this study is that the majority of children who show low performance at the time of school entry are unlikely to have the process reversed within the present education programs when they are in the school system. These findings are

all compatible with what we now know about experience-based brain development in the early years.

Gomby (2005) has reviewed the evidence concerning home visiting programs. Home visiting is a widely used approach to help families with young children in developed and developing countries. This is an attractive strategy because it can bring support to socially or geographically isolated families and the services can be tailored to meet the needs of individual families. These programs can be delivered to families with pregnant women, infants, toddlers and young children under the age of five. Home visiting programs can also be part of center-based programs. Most of these programs not associated with center-based initiatives have produced modest benefits. This is perhaps not surprising since early child development is dependent upon the degree of the interaction of caregivers with infants and toddlers and the degree of social support. Center-based programs working with parents (including home visits) are better able to deliver an integrated "dose effect" for early child development. Olds' Nurse Family Partnership Program is a randomized controlled trial (Olds et al, 2004). The effects on child development in this study in terms of child development outcomes were significant but modest (effect sizes from .03 to .25). In these studies some of the children in the home visiting program also became enrolled in preschool Head Start or licensed daycare programs. It seems that part of the Olds' programs can be considered as a combination of home visiting and center-based activities.

The U.S. Infant Health and Development Program (IHDP) study of children from birth to age 3 has examined cognitive and language development. The investigators found that the quality of the child's program during this period has a significant effect on outcome by age 3 (Brooks-Gunn et al, 2002). Brooks-Gunn concluded from their work with the IHDP data that high quality center-based care showed excellent results on early child development (Hill et al, 2002). Brooks-Gunn has concluded that the provision of universal high quality center-based childcare is beneficial to everyone including children solely cared for by their mothers. She concluded that these positive benefits continued into the late elementary and high school years.

In their studies of low birth-weight premature infants, Brooks-Gunn and her colleagues found sustained effects of center-based programs (age 1 to 3) on the WISC verbal scores at age eight (Hill et al, 2003). The center-based programs were started at year one and carried on to year three. This program included home visits. Since the children were all premature, they had appropriate healthcare after birth. A striking finding in this study was the children who used the center-based program for more than 400 days over the two year period had much better verbal scores at age 8 than the children who spent less time in the early years centers. The children who attended these centers scored much better than the children who were not randomized to the center-based programs. This is good evidence of a dose effect in the one to three year age group on brain development in the early years of development for premature infants. Again, these findings are congruent with what we know about adequate and frequent stimuli influencing the biology of brain development in the very early years and that there is a dose effect in how neurons form their synapses.

It is estimated that around 40% of children under the age of five are stunted in developing countries (de Onis et al, 1993). Grantham-McGregor (1991) and colleagues set out to examine the benefits for stunted children in Jamaica of nutrition and stimulation. They enrolled children age 9 to 24 months whose height was two standard deviations less than the reference point for the age and sex of this age group. The children were randomized to four groups: nutrition supplement; stimulation; stimulation plus nutrition supplement; and no intervention. The interventions were delivered in the homes through community health aides. The stunted children were compared to normal middle class children of the same age. The children were followed for 24 months. Both stimulation and nutrition improved development. Nutrition and stimulation together led to the stunted children matching the non-stunted groups' development after 24 months. They concluded that stimulation and food supplementation had significant independent beneficial effects on the children's development. This shows that nutrition by itself does not produce the same effect as when it is accompanied by stimulation. In this study, they noted that the control group for the study came from a poor neighborhood and they did not show the same development as a population of middle class Jamaican children.

Grantham-McGregor and colleagues have more recently examined the effects on IQ and cognition for these children at ages 11 to 12 (Walker et al, 2000). At this age, the children who were stimulated showed a gain in IQ and cognitive function but this was less than the IQ and cognitive levels for non stunted middle class children. The children given only improved nutrition did not show a gain in cognition and IQ at age 11 to 12. They concluded that growth restriction in the very early years has long-term functional consequences. In other studies, interventions that begin with pregnancy appear to have larger effects (Walker et al, 2000).

In a study in Cali, Colombia, food supplementation alone did not benefit the children but combined with stimulation had substantial benefits (McKay, 1983). A recent study by Berkman et al (2002) found from their study in Peru that malnutrition in early childhood associated with diarrhea was associated with poor cognitive function at age 9. They concluded that strategies to improve cognitive function of school age children in less developed countries should focus on securing the nutrition and well-being of children in early life. Following a detailed study of nutrition in Guatemala, Brown and Pollitt (1996) concluded that improved nutrition in the early years of life substantially improved the performance in the education system. All this is in keeping with the finding that nutrition and a good developmental environment are necessary for optimal early child and brain development. In Nepal, early child development programs beginning at age three with stimulation and involving parents substantially improved school performance in comparison with children not in the programs (UNICEF, 2003).

There are a number of studies of interventions in the developing world that improve early child development (Young, 1997, 2002).

The Perry Preschool program (Berrueta-Clement, 1984; Schweinhart, 2004, 2005) (Ypsilanti study) in the United States found in a randomized trial that a center program

during the school year for three to four year olds on weekday mornings along with a weekly 1-1/2 hour home visit to each mother and child on weekday afternoons during the school year had a significant effect on child development. Fifty-eight of these children were randomized to the preschool program and 65 received no preschool program. The children in the program significantly outperformed the no program group. (Sixty-five percent in the program graduated from high school in comparison to 45% of those not in the program.) A higher proportion of the children in the program went on to university. The children in the program performed much better on the literacy tests.

Another key finding from the Ypsilanti study was the substantial reduction in crime by the individuals (reduced antisocial behaviour) in the intervention group. The reduction in antisocial behaviour was substantial leading to far fewer violent crimes, property crimes, or drug crimes. The economic return to society of the program was $258,888 per participant on an investment of $15,166 per participant - $17.07 per dollar invested. Of that return, $195,621 went to the general public ($12.90 per dollar invested) and $63,256 went to each participant ($4.17 per dollar invested). Of the public return, 88% came from crime savings, 4% came from education savings, 7% came from increased taxes due to higher earnings, and 1% from welfare savings (Schweinhart et al, 2005). Although this program had an initial effect on IQ, it was not sustained. This is perhaps not unexpected since the weight of the evidence today is that IQ is strongly influenced by the conditions during infancy (Wickelgren, 1999; Campbell et al, 2001; Schweinhart et al, 2005). The Ypsilanti Study is by today's standards a late intervention study. It is better to start programs to enhance early child development when new mothers are pregnant and certainly when the child is born.

The Abecedarian project (Campbell and Ramey, 2002; Ramey et al, 2000), a randomized trial in North Caroline provides important information about the value of early intervention with a high quality early child development program on cognitive development over more than 20 years. In this program, a group of African American children whose mothers had IQ's ranging from 74 to 124 (average 85) were randomized initially into two groups: a control group, and a group exposed to a preschool center-based program starting at four months of age. At the time of school entry, the intervention group was randomized into two groups one of which was put into a special school program for the first three years and the other went into the normal school program. The control group was also randomized into a group given the special three-year education program in the school and the others given the standard educational program. The control group randomized at the time of school entry, showed for the group given the special three year program, better performance in reading skills than the control group not randomized to the school program. The children in the original preschool intervention group showed substantially improved skills in reading and mathematics throughout the period in the school system. The children in the preschool program not placed in the special three-year school program lost a significant portion of their gain by age 21 in contrast to the group from the preschool program that also had the special three year program in the first three years of school. The findings for mathematics showed a benefit of the preschool program. This study showed that integration of the preschool and school program produced the greatest gains in reading.

This evidence is compatible with there being brain sensitive periods in the early years for language and literacy development, which influence later periods of development in the school system. The preschool program clearly enhanced performance in the school program. This evidence is compatible with the conclusions from the neurosciences and biological sciences that to improve literacy the investment in the preschool period is important. The preschool program with meaningful effect sizes on reading and mathematics skills have persisted into adult life. The three-year program in the school maintained the preschool benefits for reading. The three-year school program had an effect but it was weaker than the effect for children who had the preschool plus school program.

Mathematical ability is an example of experience in the immediate preschool period affecting performance in the school system. Case (1991; 1999) and colleagues examined whether performance in mathematics in school years could be improved through an initiative called *Right Start.* The strategy, using what they described as "the cognitive weight of numbers," uses multiple sensing pathways (touch, vision and sound proprioception) and, probably, is influenced by the cross-modal information exchange that the sensing pathways develop in early life. In this study, children in a poor socioeconomic neighborhood were randomized into an intervention group and a control group and compared with children in a middle-class school. At age 9, the children participating in the special preschool intervention program surpassed the children in the middle class school, whereas the children in the control group performed less well than those in the middle class school. Case speculated that individuals who miss this sensitive period of development might have difficulty with complex mathematics later in life. Their findings are compatible with the findings of critical and sensitive periods of brain development in the early years.

Case's findings are compatible with the conclusions of Fuchs and Reklis (1994), who examined the effects of early child development on the mathematics performance of students in various U.S. states. They found that a state's mathematics performance in schools was high when children entering the school system had good early child development and low in states where early child development was poor. They concluded that strong early child development programs are required to improve the mathematics performance of U.S. students. This conclusion is compatible with the findings from the Abecedarian project and our understanding of experience and brain development in the early years.

Lee and Burkam (2002) showed for the U.S. that the mathematics and reading achievement for American children at the beginning of kindergarten was a gradient when plotted against socioeconomic status.

The studies that have been discussed in addition to the population-based measurements given in the earlier sections, directly or indirectly bring out the importance of social and community support systems. In the Canadian longitudinal study of children and youth, Doug Willms (2002b) assessed the effects of reading and social support on child development in the four to six year age group. He found that the socioeconomic gradient

was not evident when the children were assessed on the basis of the community support for families with young children or the extent of reading to children in early life. The significance of these observations is that social support and reading (stimulation) affects children in all social classes and improves outcomes.

There is evidence that the quality of a society in terms of being stable and non-violent influences early child development. In a study of the health of children in the Israeli Palestine conflict in Gaza (Miller, 2000), it was found that the children in the Gaza Strip in comparison to children of the same age in the middle class in Hamilton, Ontario had significantly greater emotional behaviour problems. The incidence of these disorders in children from the Gaza Strip was approximately three times that of children of equivalent age in middle class families in Hamilton. This is strong evidence that the stability and quality of a society has a significant effect on early child development. It also means that in countries in the developing world that have social instability and violence, improving conditions for early child development will be extremely difficult and lead to adult populations with significant antisocial behaviour problems.

A question that frequently comes up is, will interventions improve the quality of all social classes in a population? There is evidence from some countries that universal high quality center based early child development programs will raise the competence and quality of all sectors of society. The OECD literacy assessments (prose, qualitative, and quantitative), show the adult populations in some countries have high performance and fairly flat socioeconomic gradients (Denmark, Norway, Sweden, and Finland). All of these countries provide high quality early child development programs. Their investments in early child development are substantial in comparison to countries like Canada (OECD, 2001). This evidence strongly supports the concept that universal accessible programs will substantially increase the competence and quality of all sectors of a population. The data from Cuba (see section on Literacy) showing a high performance in literacy with a fairly flat socioeconomic gradient is an indicator that good early child development programs will affect mixed populations. Cuba has for more than 30 years had probably the best early child development programs beginning at birth in Latin America. The health statistics for the OECD countries correlates with their literacy performance.

Summary: The results from these and other studies are compatible with the evidence from the neurosciences and biological sciences that the critical and sensitive periods for brain and biological development that are significantly influenced by experience in the early years beginning with pregnancy. A substantial investment in early child development will be necessary if we are to improve the competence, health, and well-being of populations throughout the world.

COMMUNITIES AND MEASURES OF EARLY CHILD DEVELOPMENT

Early child development is profoundly affected by the quality of caregiving (including parents) in the early years including pregnancy and the degree of support provided to the caregivers. Initiatives to ensure high quality early child development require the involvement of the parents along with appropriate institutional support. These initiatives should provide arrangements for non parental care (day care), effective interaction of the children with the caregivers and other children. Non-working mothers should be participants in these early child development centres. The programs should optimize development of the sensory pathways in all periods of early development (infancy, toddlers, and young children). There should be a healthy environment and adequate resources for reading and play-based learning. Play-based learning if properly designed is actually problem-based learning which is one of the best strategies for brain development as well as for learning. These initiatives should include prenatal and postnatal support. Parents must be involved in these programs and if there are center-based programs, parents should be involved in the work of the centers. Home visiting can augment the work of center-based early child development initiatives. Finally, it is important to integrate the early child development programs with the primary school system and it is logical that if there are kindergarten programs, they should become part of the early child development center. This is described in McCain and Mustard (1999) report to the Ontario government.

In their proposal "Success by Ten", Ludwig and Sawhill (2006) outline three important principles to improve early child development: 1) intervene early; 2) intervene often; 3) intervene effectively. This is in agreement with all the evidence we now have. Studies from the neurosciences and biological sciences, health, and the social sciences indicate that experience in early life including in utero period has significant effects. Ludwig and Sawhill also make the point that programs to improve development in the early years should also feed into quality elementary school programs. It is logical to integrate early child development programs with the elementary school system. Finally, to intervene effectively in early child development will cost more money than developed societies spend. It is important that the money allocated for early child development be spent on quality programs with well-qualified staff. Many so-called day care initiatives are not high quality early child development programs.

There is increasing public interest in effective initiatives for high quality early child development. Communities and families are interested in knowing how well their children are developing. Communities are becoming increasingly interested in keeping score to learn what has gone wrong and, even more, find out what is going right for young children in their communities. For any society interested in the future quality of its population, it must have some assessment of how well it is fulfilling its responsibility for the rights of the child to be optimally prepared for adult life. This is not a new idea for society, since when we recognized the importance of pregnancy and the very early years of development on the health of mothers and infants, we gradually adopted local and national measures of maternal and infant mortality. It is only logical that this

approach be broadened to assess the effects of child development programs on health, learning, and behaviour in infants and young children.

In many regions, attempts have been made to put in place "readiness to learn" measures (Rock and Stenner, 2005). In order to develop a measurement tool in Canada that would assess in communities the outcomes in child development in respect to health, learning, and behaviour, Magdalena Janus and Dan Offord (2000) developed the Early Development Instrument (EDI). In setting this up, they proposed that it should have the following characteristics:

1. A population level measure: results could be interpreted for groups of children and not individuals.
2. Based on several months of observation, the Instrument is completed by teachers in the kindergarten classes.
3. The results will be used by communities to identify the weak and the strong sectors of a community.
4. The measure should be used to mobilize communities to set out steps to improve outcomes.

The Instrument assesses five child development characteristics.

1. Physical health and well-being
   - Above the 90th percentile, a child is physically ready to tackle a new day at school, is generally independent, and has excellent motor skills.
   - Below the 10th percentile, a child has inadequate fine and gross motor skills, is sometimes tired or hungry, usually clumsy, and may have flagging energy levels.

2. Social Competence

   - Above the 90th percentile, a child never has a problem getting along, working, or playing with other children; is respectful to adults, self-confident, has no difficulty following class routines; and is capable of pro-social behaviour.
   - Below the 10th percentile, a child has poor overall social skills; has regular serious problems in more than one area of getting along with other children, accepting responsibility for their own actions, following rules and class routines, respect for adults, children, and others' property, with self-confidence, self-control, adjustment to change; is is usually unable to work independently.

3. Emotional Maturity

   - Above the 90th percentile, a child almost never shows aggressive, anxious or impulsive behaviour, has good ability to concentrate, and is often helping other children.

- Below the 10th percentile, a child has regular problems managing aggressive behaviour, is prone to disobedience, and/or is easily distractible, inattentive, impulsive, usually unable to show helping behaviour towards other children, and is sometimes upset when left by the caregiver.

4. Language and Cognitive Development

    - Above the 90th percentile, a child is interested in books, reading and writing, and rudimentary math, is capable of reading and writing simple sentences and complex words, and is able to count and recognize numbers and geometric shapes.
    - Below the 10th percentile, a child has problems in both reading/writing and numeracy, is unable to read and write simple words; is uninterested in trying, and often unable to attach sounds to letters, has difficulty with remembering things, counting to 20, recognizing and comparing numbers, and is usually not interested in numbers.

5. Communication Skills and General Knowledge

    - Above the 90th percentile, a child has excellent communication skills, can tell a story and communicate with both children and adults, has no problems with articulation.
    - Below the 10th percentile, a child has poor communication skills and articulation, limited command of English, has difficulties in talking to others, understanding and being understood, and has poor general knowledge.

This measurement has now been applied widely across Canada at the time children enter kindergarten. The results from the Vancouver study (Hertzman et al, 2002) on more than 9,000 children entering kindergarten, clearly demonstrated a social economic gradient in the quality of early child development. In this assessment, it was clear that 80% of the vulnerable children live outside the conventional high risk neighbourhoods. A higher proportion of children in the high-risk neighbourhoods were vulnerable but children in the middle class neighbourhoods were vulnerable. In Canada, the largest number of vulnerable children were in the middle class. Of equal importance in these findings is that the schools with the greatest proportion of children coming in with poor development had the poorest test results in grade 4 and grade 7 on the Foundation Skills Assessment of the provincial government of British Columbia. In Toronto (City of Toronto, 2003; Founders' Network, 2004), similar findings were obtained showing that the grade 3 and grade 6 literacy tests were poorest in the schools with the greatest number of children showing low scores on the EDI assessment at the time of school entry. From a population-based assessment, the schools did not substantially change these values for literacy between grade 3 and grade 6. These findings are in keeping with the earlier studies of Fuchs and Reklis (1994) in which they pointed out that to improve the

mathematics scores in U.S. schools, communities would have to put in place high quality programs for early child development before children start elementary school.

Since these measures have been introduced in different parts of Canada, some communities are now taking steps to improve early child development outcomes across all social classes. It is essential for communities to have outcome measures for early child development that are not a screening tool to identify children with special needs, does not diagnose children with special learning disabilities, does not select children to be placed in special education categories and is not used to develop curricula for early child development programs. The EDI is simply an instrument to let communities know what the quality of early child development is in their community. With adequate information and support, communities, their families and governments can take steps to produce improved early child development for which the long-term effects will be a healthy population with fewer behaviour problems, and a high quality competent population.

In today's changing world, there is no doubt that we need to put in place programs that provide quality early child development programs for families with infants, toddlers and young children will substantially improve the competence and quality of the next generation. If we are to reduce the proportion of the population in poverty, improve equity in literacy and income, reduce violence, enhance social stability, and improve the quality of human capital which is increasingly important for a knowledge-based economy, societies have to invest in early child development. This has to be a crucial objective for all regions of the world if we are going to continue our experiments in civilization and take account of the future in respect to sustaining our biosphere and our populations.

ECONOMIC AND POLITICAL CONSIDERATIONS

Our attempts to reduce global poverty among the world's populations will be impossible to accomplish unless we can achieve equity in literacy and health in all regions of the world. If we are anxious to establish a democratic, tolerant, equitable, prosperous, sustainable world, we will have to make investments in early child development a high priority if we are to improve the competence and quality of populations. The differences in levels of human development in different parts of the world as demonstrated by the international literacy and health studies raises the concern that we may not be able to improve the quality and competence of populations without outstanding leadership and innovation from the major international organizations such as the United Nations and its agencies, WHO, international banks such as The World Bank, the Asian Development Bank, and the Inter-American Development Bank.

The World Bank in its 2006 World Development Report (2005) raises the question of equity and development. Paul Wolfowitz, the new president of the bank is interested in improving equity,

> Equity is defined in terms of two basic principles. The first is equal opportunity: a person's life achievements should be determined primarily by his or her talents and efforts, rather than by predetermined circumstances such as race, gender, social and family background, or country of birth. The second principle is the avoidance of deprivation in outcomes, particularly in health, education, and consumption levels (page xi).

The discussion of equity in the report states:

> Equity and fairness matter not only because they are complementary to long-term prosperity. It is evident that many people – if not most – care about equity for its own sake. Some see equal opportunities and fair processes as matters of social justice and thus as an intrinsic part of the objective of development. In chapter 4, we briefly review arguments and evidence suggesting that most societies exhibit a pervasive and long-standing concern for equity (page 75).

The dark side of this challenge is brought out in the books by Ehrlich (2000), Diamond (2005), Wright (2004) and others. The pessimists among these authors point out that the risks for all of us are real and that without a more collective approach to improve the competence and quality of all populations, it may not be possible to avoid significant negative influences in societies that could lead to disruption of our civilizations, excessive violence and loss of life, chaos, and a return to less democratic governance.

An important consideration is that we now have a better understanding of the determinants of economic growth and civic societies (van der Gaag, 2002). It is

interesting that among the Nobel Prize winners in Economics, Tinbergen, the first Nobel Laureate, pointed out the competence of the labour force was an important production factor. Fogel, the 1993 Nobel Prize winner in Economics, also brought out the importance of "people development". Sen, in 1998, emphasized the importance of the quality of populations and their societies in respect to economic growth. In a recent Brookings Working Paper, Dickens, Sawhill and Tebbs (2006) discuss the effects of investing in early child development on economic growth. They conclude that investment in early child development will have a net economic benefit to individuals and societies. They make a crucial point,

> "Because most of these benefits are longer term while the costs of mounting the programs are more immediate, the political system tends to be biased against making such investments. But any business that operated in this way would likely fail to succeed. A similarly dim prospect may be in store for a country that fails to take advantage of such solid investment opportunities."

We now know what we have to do to improve the competence and quality of populations and improve our potential to establish pluralistic, tolerant, equitable, prosperous, democratic, stable, sustainable communities in a globalized planet. Having discussed this subject at the World Bank several years ago (Young, 1997, 2002), why is there such a gap between what we know and what we do locally and internationally? There are many reasons, but when many of the leading nations in the world with great wealth fail to understand the problem and improve the quality of their populations (improve and flatten the gradients in health and literacy and reduce the inequities in their societies), it has to be a major concern to everyone. Can international organizations such as the United Nations and World Bank rise above the failure of many wealthy developed countries to provide the support and resources necessary to improve early child development and the competence and quality of populations in all countries?

Jacques van der Gaag (2002), at the 2000 World Bank meeting on child development emphasized the point that the quality of human capital is important for economic growth and social stability. He made the point that in the early models of the determinants of economic growth, the quality, competence and behaviour of the population was not given the consideration it deserved. Recently, Helpman in his book, *The mystery of economic growth* (2004), emphasized the importance of the quality of human capital. Jacques van der Gaag (2002), in bringing all these points about human development together at the World Bank meeting in 2000, concluded that early child development affects education, health, the social capital of societies, and the overall equality, which he referred to as a "level playing field", and that this is key for stable societies and economic growth.

> For adults equality in education and health leads to equality of opportunity; better education and health lead to higher income. Significantly, data show that countries with a more equitable distribution of income were also more healthy. The evidence is undeniable, yet the reasons for the relationship are being debated. Nevertheless, the link

> between more equality of opportunity early in life and more equality in education, income, and health later in life appears to be strong, as does the aggregate link between greater equality in income and the health of a society. And again, the benefits begin with early child development (van der Gaag, 2002).

The exponential growth in knowledge and advanced technologies in this period of human history requires societies to build competent high quality populations to build and sustain stable, prosperous, communities. Failing to make the investments in the quality and competence of future populations could lead to chaos and grim prospects for our continuing experiments in civilizations.

Heckman (2000), a University of Chicago Nobel Laureate in Economics has done a detailed analysis in the U.S. of the return on investment at different stages of development on the competence and qualities of the U.S. population. He has concluded from the study of human development in the U.S. that the return for every dollar invested preschool is much greater for the individual and society than the investment in school based programs. The return on investments in education is about three to one in contrast to at least eight to one for early child development programs. (This calculation does not include the effects of early child development on physical and mental health in adult life.) In one of his papers he states:

> We cannot afford to postpone investing in children until they become adults nor can we wait until they reach school – a time when it may be too late to intervene (Heckman, 2000).

Several years ago *The Economist* (1998) in an article about the importance of early child development in respect to developed countries wrote:

> The principle of free education for school-age children is already entrenched throughout the rich world; there would be nothing incongruous about extending it further down the age range.

The challenges to improve early child development in less developed countries are more difficult than in developed countries. Less developed regions, such as Africa, have more than 20% of their 140 million children at very high risk for poor development. More than 95% of these young children do not have access to early child development programs that provide healthy environments, good nutrition and stimulation. It is not surprising that of the children in the world who do not attend school, nearly 50% are in Africa. In twelve African countries as a consequence of AIDS and war and civil strife, orphans will comprise 20% of the children under 15 years of age. We now know enough about factors influencing early child development to avoid putting these children in traditional orphanages that are at very high risk of severely damaging their development (Young and Mustard, in press).

Societies in the developing world will not be able to make the investments to ensure good early child development unless international agencies such as the World Bank, the United Nations and other international organizations provide more support and leadership. One needs to ask the question within these international agencies; "why is there such a gap between what we know and what we do?" If we do not close this gap, there is a high risk that given the conditions of today's world, there will be a substantial failure to improve the competence and well-being of populations and improve equity, that could put our societies and experiments in civilization at risk.

Wright (2004) in his Canadian Broadcasting Corporation 2004 Massey Lecture presents a clear outline of the scale of the challenge we face:

> Yet despite the wreckage of past civilizations littering the earth, the overall experiment of civilization has continued to spread and grow. The numbers (insofar as they can be estimated) break down as follows: a world population of about 200 million at Rome's height, in the second century A.D.; about 400 million by 1500, when Europe reached the Americas; one billion people by 1825, at the start of the Coal Age; 2 billion by 1925, when the Oil Age gets under way; and 6 billion by the year 2000. Even more startling than the growth is the acceleration. Adding 200 million after Rome took thirteen centuries; adding the last 200 million took only three years (Wright, 2004, page 109)…
>
> … We have the tools and the means to share resources, clean up pollution, dispense basic health care and birth control, set economic limits in line with natural ones. If we don't do these things now, while we prosper, we will never be able to do them when times get hard. Our fate will twist out of our hands. And this new century will not grow very old before we enter an age of chaos and collapse that will dwarf all the dark ages in our past (Wright, 2004, page 132).

We have to enhance the competence and quality of populations to be able to understand the issues and their importance and establish appropriate local, national and global institutions to improve human development. With fifty percent of the population in the U.S. and Canada showing poor literacy capability and understanding inadequate for today's knowledge based societies, can we in developed countries take the steps to improve the competence and quality of our populations and demonstrate what can be done?

We have the knowledge to improve the health, well-being and competence of populations within and across countries and set in place economies based on sustainable development. Surely, the task of developed countries is to demonstrate how to apply this knowledge and improve the health, well-being and competence of our populations and to identify the causes of the gaps between what we know and what we can do and take steps to close this gap.

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This paper was prepared for The World Bank International Symposium on Early Child Development – A Priority for Sustained Economic Growth & Equity, September 27-29, 2005. Keynote Presentation by Dr. J. Fraser Mustard, Science of ECD: Biological Embeddings of Early Child Development. Excerpts of this paper are under preparation for publication by The World Bank.

FIGURE 1

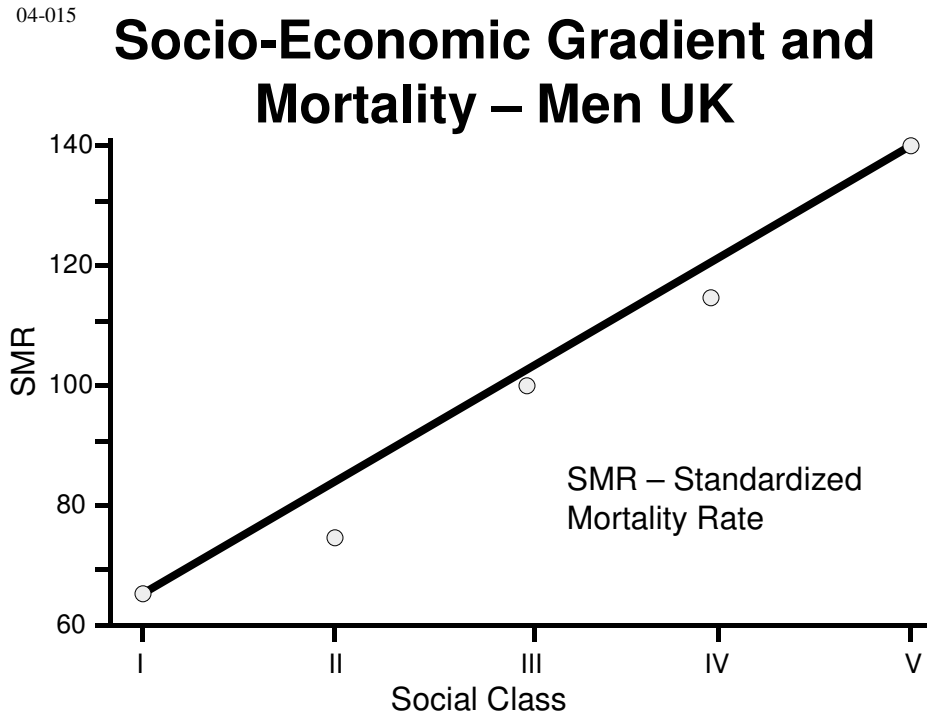


Figure 1 – Adapted from Marmot, M., M. Bobak, and G. Davey Smith. Explanations for Social Inequalities in Health. In: *Society & Health*. Amick, B.C., S. Levine, A.R. Tarlov, and D. Chapman Walsh. Eds. New York: Oxford University Press. 1995.

FIGURE 2

91-068

U.K. CIVIL SERVICE
Mortality - All Causes

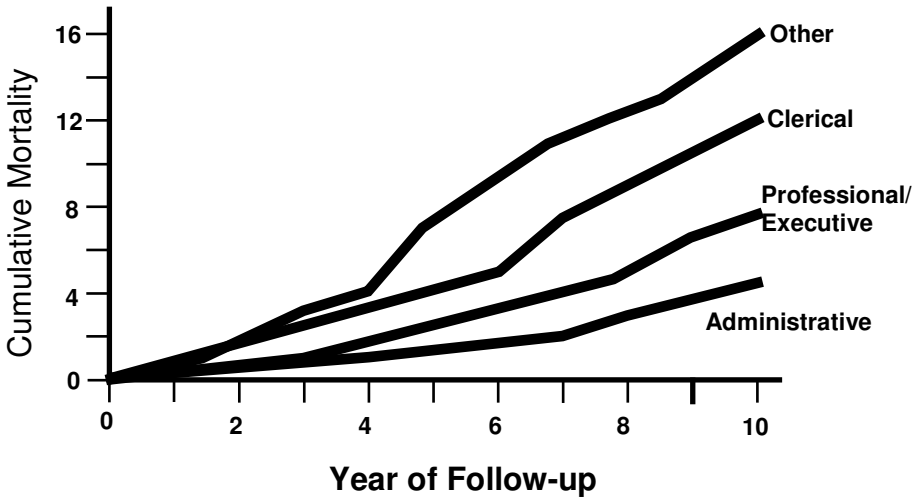


Figure 2 – Age Adjusted Mortality Rates (percentage) by Grade of Employment for Whitehall civil servants age 40-64.

Adapted from Marmot, M., Social Differentials in Health. In: Daedalus. Journal of the American Academy of Arts and Sciences. Health & Wealth. Fall 1994.

Marmot, M., M. Bobak, and G. Davey Smith. Explanations for Social Inequalities in Health. In: *Society & Health*. Amick, B.C., S. Levine, A.R. Tarlov, D. Chapman Walsh. Eds. New York: Oxford University Press. 1995. (Source: Marmot, M.G. et al. 1991. Health inequalities among British civil servants: the Whitehall II Study. *The Lancet* 337:1387-1393).

FIGURE 3

03-012

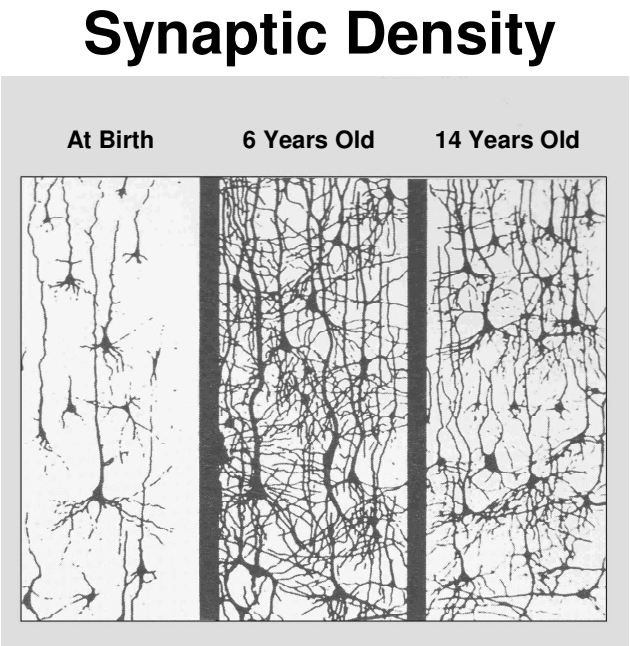


Figure 3 – From *Rethinking the Brain*. Shore, Rima. 1997. Families and Work Institute.

FIGURE 4

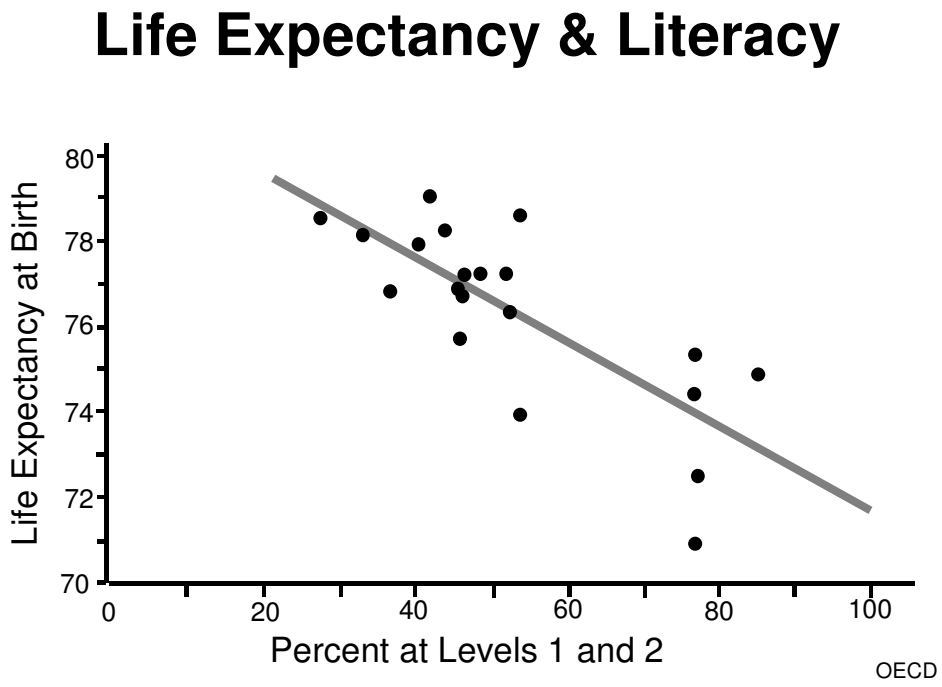


Figure 4 – This shows the relationship between life expectancy and proportion of the population at low levels of literacy (Levels 1 and 2) in the OECD study of developed countries. Adapted from *Literacy in the Information Age: Final Report of the International Adult Literacy Survey.* 2000. OECD and Statistics Canada. p. 82.

FIGURE 5

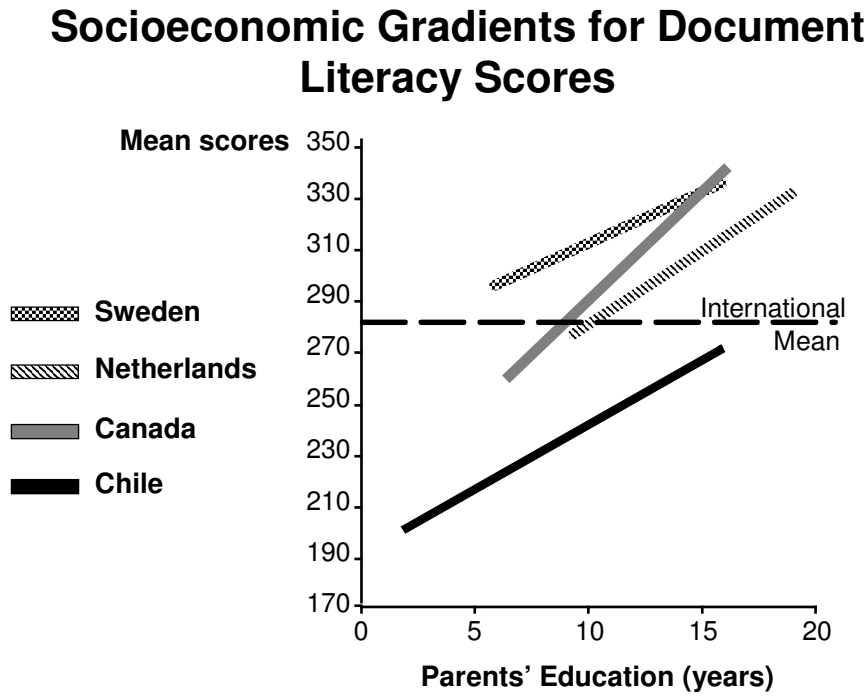
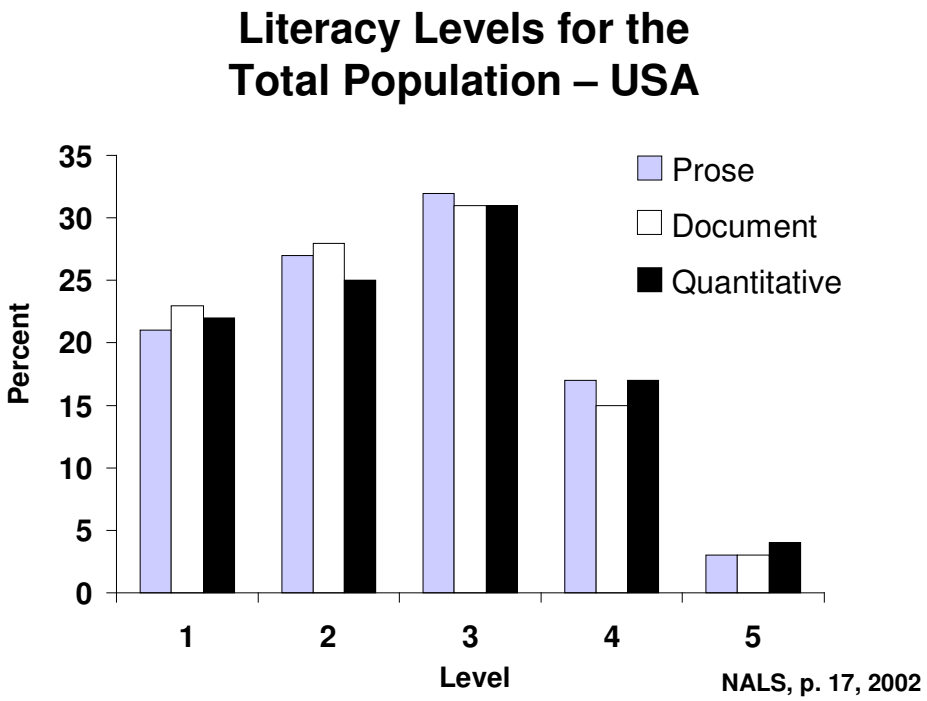


Figure 5 – Adapted from *Literacy in the Information Age: Final Report of the International Adult Literacy Survey.* 2000. OECD and Statistics Canada. p. 32.

FIGURE 6

Figure 6 - This figure shows the recent study of literacy in the U.S. adult population.



Adapted from *Adult Literacy in America: A First Look at the Findings of the National Adult Literacy Survey*. U.S. Department of Education. 2002. Nearly 50% of the U.S. population is at Levels 1 and 2 (low) and about 5% are at Level 5 (high).

FIGURE 7

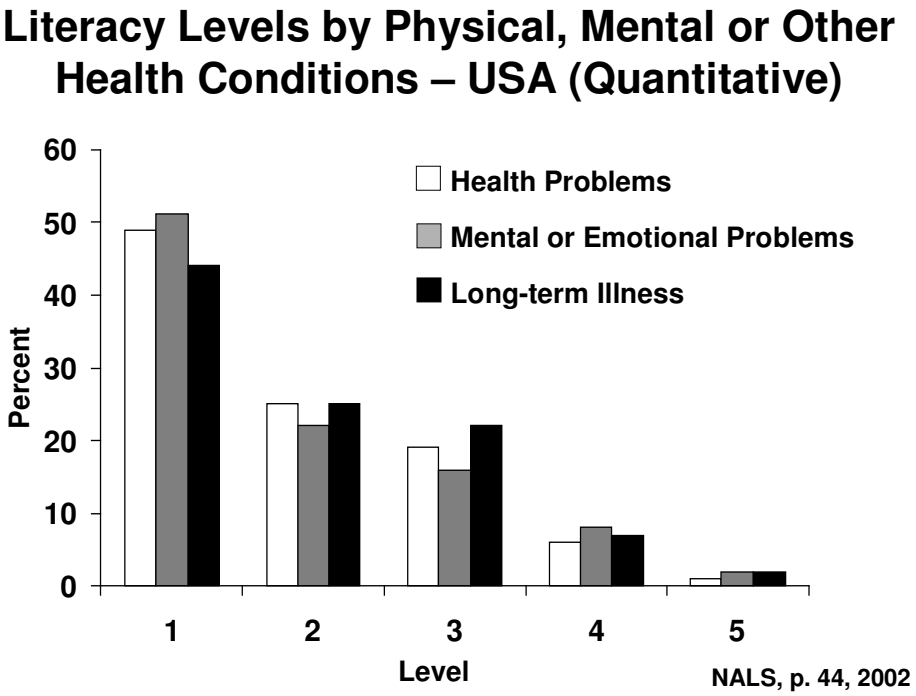


Figure 7 – Adapted from the recent U.S. assessment (*Adult Literacy in America: A First Look at the Findings of the National Adult Literacy Survey*. U.S. Department of Education. 2002) shows the competence of the adult population in literacy and the burden of physical and mental health problems. In terms of the literacy assessments, Level 1 is low and Level 5 is high.

FIGURE 8

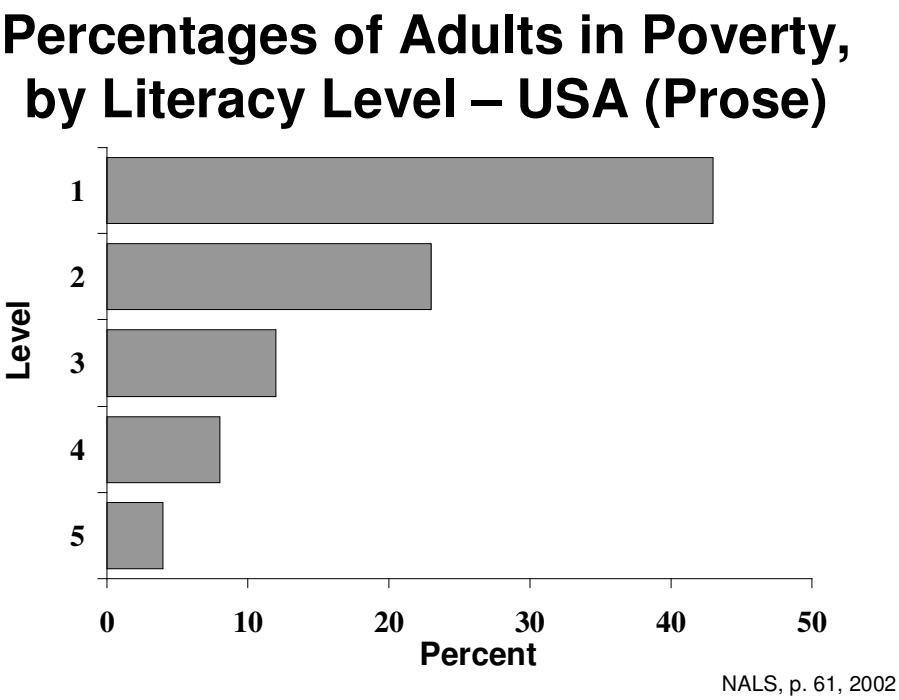


Figure 8 – Adapted from the U.S. study, (*Adult Literacy in America: A First Look at the Findings of the National Adult Literacy Survey*. U.S. Department of Education. 2002), the percentage of the population living in poverty by U.S. measures was greatest in the population at the low level (Level 1) of literacy performance.

TABLE 1

Document Literacy
Ages 16 to 65

	Level 1 and 2	Level 4 and 5
Sweden	23%	34.0%
Canada	42% (42.6%)	23.0% (20.5%)
Australia	43%	17.0%
United States	48% (52.5%)	18.0% (15.1%)
Chile	85%	3.0%
Mexico	84%	1.7%

Table 1 – Mexico data and data in brackets are from the second OECD literacy report, *Learning a Living: First Results of the Adult Literacy and Life Skills Survey*, Statistics Canada and OECD, 2005. Other data are from, *Literacy in the Information Age*. Statistics Canada and OECD, 2000.