



# RentSafe Background Paper on Housing-Related Health Risks<sup>1</sup>

October 2015

## 1. Introduction

For most Canadians a healthy home is a home in good physical condition that provides adequate heat in cold weather, sufficient light and ventilation, security from intruders, as well as the basic services of a safe and adequate water supply, sewage disposal, and household waste collection. These requirements are reflected in current Canadian building, fire and plumbing codes, as well as public health regulations. Yet approximately 7% of Canadian homes, in need of major structural, plumbing, or electrical repairs, would not meet this basic definition.<sup>2</sup>

Our understanding of healthy housing is also evolving beyond these basic requirements, as new knowledge of environmental risks comes to light. The serious health impacts of environmental tobacco smoke, mould, radon, and lead in old paint are now widely recognized. More recent research has raised concerns about our exposure to other indoor chemicals, including pesticides, volatile organic compounds (VOCs), flame retardants, and plasticizers, as well as the potential risks of living with increasing electromagnetic radiation from the growing use of wifi, cell phones, and other wireless devices. Investigation into the health outcomes associated with indoor chemical exposures is ongoing, and in the case of electromagnetic radiation, still in the early stages.

The main goal of this paper is to briefly describe current scientific knowledge on a wide range of environmental health risks in the home. The topics are organized according to the type of hazard: (i) biological, (ii) chemical, or (iii) radiation. Physical hazards in the home, such as structural defects or faulty electrical or heating systems, are not directly discussed in the background paper, but are

---

<sup>1</sup> This paper served as a backgrounder for the inaugural meeting of the RentSafe Advisory Committee held in Toronto on October 27, 2015, and forms part of the RentSafe baseline work. It was prepared for the Canadian Partnership for Children's Health and Environment (CPCHE) and the CPCHE-led RentSafe initiative by Deborah Schoen, under contract with the Environmental Health Institute of Canada and with funding provided by the Ontario Trillium Foundation.

<sup>2</sup> Statistics Canada 2006 Census: <http://www.statcan.gc.ca/tables-tableaux/sum-som/101/cst01/famil63b-eng.htm>

described in detail in some of the references.<sup>3</sup> Such hazards represent an important public health issue, as they can lead to serious injury from falls, electrical shock, or fires. However, the focus of this paper is on environmental health issues, with emphasis on conditions often found in low-income housing and on health risks of particular concern for children, and with recognition of the stark reality that one in three Canadians households experience substandard conditions or other form of housing need.<sup>4</sup>

## 2. What determines health?

A person's physical and mental health is strongly influenced by individual traits, circumstances, and behaviours as well as the physical, social and economic environment in which he or she lives. The set of factors that collectively impact health are referred to as determinants of health.

Age and gender are obvious determinants of health. The risks of injuries, infectious diseases and chronic illnesses vary between men and women, adults and children. Yet for many years environmental research and policies did not address age and gender differences. In recent decades scientists have actively sought to fill in this gap, especially with respect to children's health.<sup>5</sup>

Children are particularly vulnerable to toxic substances in the environment for reasons that are now well-documented:<sup>6</sup>

- Children are more exposed to contaminants: they eat, drink and breathe in more food, water and air than adults in relation to their size. Children also ingest greater amounts of house dust and soil, in which many contaminants accumulate, as they play closer to the ground and frequently put their fingers and other objects in their mouths;
- As the fetus, infant and child grows to adulthood, his or her organ systems continue to mature. Exposure to environmental toxins may disrupt this development at key stages, potentially leading to permanent dysfunction;

---

<sup>3</sup> See for example Centers for Disease Control and Prevention and U.S. Department of Housing and Urban Development. "Healthy Housing Reference Manual." Atlanta: US Department of Health and Human Services, 2006. [www.cdc.gov/healthyhomes/publications.html](http://www.cdc.gov/healthyhomes/publications.html).

<sup>4</sup> Waterston, S., Grueger, B., Samson, L., Canadian Paediatric Society Community Paediatrics Committee. "Housing need in Canada: Healthy lives start at home." *Paediatr Child Health* 2015;20(7):403-0.

<sup>5</sup> Landrigan, P.J., and J.E. Carlson. "Environmental Policy and Children's Health." *The Future of Children / Center for the Future of Children, the David and Lucile Packard Foundation* 5, no. 2 (1995): 34-52.

Lewit, Eugene M., and Linda Schuurmann Baker. "Children's Health and the Environment." *The Future of Children / Center for the Future of Children* 5, no. 2 (Summer/Fall 1995): 8-10.

<sup>6</sup> Landrigan, P.J., and L.R. Goldman. "Children's Vulnerability to Toxic Chemicals: A Challenge and Opportunity to Strengthen Health and Environmental Policy." *Health Affairs* 30, no. 5 (2011): 842-50.

- Children have more years ahead of them in their lifetimes. This leaves more time for the development of chronic diseases, which may be triggered by early exposures or a buildup of exposures.

Income and education are important and well-documented social determinants of health.<sup>7,8</sup> Studies of many different populations have shown that individuals with less money and less education have poorer health and a lower life expectancy. But the magnitude of the impact of income on health varies between communities, regions and countries. Other factors can either amplify or reduce the association between income and health – including access to health care and other services, race and discrimination, language, cultural traditions, as well as social support from family and community.

In this light housing can be seen as a mediator between a family's income level and their health. The direct health impacts of substandard housing are magnified by other impacts associated with low income. Affordable healthy housing, on the other hand, contributes to a family's health and well-being, and plays a role in reducing income related health inequities.

### 3. Biological hazards

#### 3.1 Dampness and mould

There is strong scientific evidence that living in a damp or mouldy home can lead to rhinitis – hayfever-like symptoms such as irritation of the eyes, nose, and throat<sup>9</sup>, as well as a worsening of asthma symptoms.<sup>10</sup> There is also evidence that mould contributes to the development of asthma, beyond triggering symptoms in people who already have the disease.<sup>11,12</sup>

---

<sup>7</sup> WHO. "Closing the Gap in a Generation: Health Equity through Action on the Social Determinants of Health. Final Report of the Commission on Social Determinants of Health." Geneva, World Health Organization, 2008.

<sup>8</sup> Braveman, Paula, Susan Egerter, and David R. Williams. "The Social Determinants of Health: Coming of Age." *Annual Review of Public Health* 32, no. 1 (March 18, 2011): 381–98.

<sup>9</sup> Jaakkola, Maritta S., Reginald Quansah, Timo T. Hugg, Sirpa A.M. Heikkinen, and Jouni J.K. Jaakkola. "Association of Indoor Dampness and Molds with Rhinitis Risk: A Systematic Review and Meta-Analysis." *Journal of Allergy and Clinical Immunology* 132, no. 5 (2013): 1099–1110.e18.

<sup>10</sup> Kanchongkittiphon, Watcharoot, Mark J. Mendell, Jonathan M. Gaffin, Grace Wang, and Wanda Phipatanakul. "Indoor Environmental Exposures and Exacerbation of Asthma: An Update to the 2000 Review by the Institute of Medicine." *Environmental Health Perspectives* 123, no. 1 (January 2015): 6–20.

<sup>11</sup> Quansah, Reginald, Maritta S Jaakkola, Timo T Hugg, Sirpa A M Heikkinen, and Jouni J K Jaakkola. "Residential Dampness and Molds and the Risk of Developing Asthma: A Systematic Review and Meta-Analysis." Edited by Thomas Behrens. *PLoS ONE* 7, no. 11 (2012): e47526.

<sup>12</sup> Dick, S, A Friend, K Dynes, F AlKandari, E Doust, H Cowie, J G Ayres, and S W Turner. "A Systematic Review of Associations between Environmental Exposures and Development of Asthma in Children Aged up to 9 Years." *BMJ Open* 4, no. 11 (November 1, 2014). doi:10.1136/bmjopen-2014-006554.

Mould is the common name for a few dozen types of fungi found everywhere in the environment. Mould spores require nutrients, warmer temperatures and moisture to grow. The indoor home environment provides warmth, as well as nutrients in the form of materials such as wood, drywall, paper, cardboard, and fabrics. If these materials become wet and stay damp for more than a day or two, mould can develop. Major mould problems in a building commonly result from water infiltration (e.g. through leaks in the roof or foundations), plumbing leaks, or flooding events. Poor insulation can also lead to condensation on cold interior walls in winter.

Normal daily activities such as showering or cooking also produce moisture. Adequate ventilation, through the use of kitchen and bathroom exhaust fans and opening windows, reduces the humidity in these rooms, and the likelihood of mould growth.

When a mould problem is identified public health agencies, such as Health Canada or the World Health Organization, recommend cleaning mouldy surfaces and removing mouldy materials that cannot be cleaned. Repairs or renovations to resolve the underlying cause of dampness are required to prevent regrowth. This advice applies regardless of the particular mould species present, as any mould growth is considered a health risk. Air or surface sampling and testing to identify and/or quantify particular mould species is not recommended, in most instances, as this may be expensive without providing additional useful information. Moreover, there are no established numerical limits on mould spores in indoor air that can be used to evaluate health risks.<sup>13,14</sup>

### 3.2 Pest infestations

Common housing pests include a variety of insects such as bed bugs, cockroaches and dust mites, rodents (rats, mice, squirrels), and sometimes larger animals such as raccoons. Aside from the discomfort, mental stress and property damage that pests cause, some pests such as cockroaches and rodents are also sources of infectious disease and allergens.

Pest control measures target particular species, taking into account their habitat and behaviours, but can generally fall into one of four strategies:<sup>15</sup> (i) preventing access (sealing holes, cracks and other openings in the building); (ii) eliminating food sources (proper disposal of household waste, keeping food in closed containers); and (iii) eliminating breeding and nesting materials near the home, for

---

<sup>13</sup>Health Canada: <http://healthycanadians.gc.ca/publications/healthy-living-vie-saine/mould-moisissure/index-eng.php>  
<http://healthycanadians.gc.ca/publications/healthy-living-vie-saine/mould-home-maison-moisissure/index-eng.php>

<sup>14</sup> World Health Organization: [http://www.euro.who.int/\\_data/assets/pdf\\_file/0017/43325/E92645.pdf](http://www.euro.who.int/_data/assets/pdf_file/0017/43325/E92645.pdf)  
US EPA: <http://www2.epa.gov/mold>

<sup>15</sup> CDC and HUD 2006 (see footnote 3).

example rubbish or firewood; and (iv) killing the pests, through traps, professional extermination services, or using pesticides available to consumers.

The first three strategies are required for long-term control of pests. The use of extermination services, in addition to non-chemical measures, may be called for in some situations (e.g. bed bug infestations). The frequent use of pesticides in the home, however, increases exposure of family members and especially young children, who have greater exposure to house dust in which pesticides accumulate. Moreover, frequent pesticide applications do not appear to be effective if the source of the pest infestation is not addressed<sup>16</sup> (see section below on Pesticides).

### 3.3 Health risks related to drinking water supplies and wastewater disposal

In most cities and municipalities, ensuring safe drinking water and wastewater treatment and disposal are the responsibilities of municipal or regional authorities. Housing should provide adequate water pressure for daily activities, well-functioning toilets and plumbing that is free of obstructions, leaks or other defects.

In rural areas, the household may be served by a private well. Shallow wells or older wells that do not meet today's construction standards are vulnerable to contamination by pathogenic bacteria from human or animal waste in surface runoff. Contamination of a drinking water supply can result in gastrointestinal illness – sometimes severe, depending on the pathogens in the water and the sensitivity and health status of residents. Infants, young children, the elderly and immunocompromised individuals (for example individuals undergoing chemotherapy) are most at risk.

For all private wells water testing for indicators of pathogens (Total Coliform and E. coli) is recommended at least three times per year. Testing is generally the responsibility of the well owner. The best times to sample are after a heavy rainfall or snow melt, and in the event of flooding, as this is when wells are most susceptible to contamination from surface runoff.<sup>17</sup>

A rural household may also have a private septic tank and drainage (absorption) field for the treatment and disposal of wastewater. Septic tanks can be a safe and reliable solution. However, the tanks must be sited an adequate distance from wells to prevent microbial contamination. Regular inspection and maintenance (for example on a yearly basis) is also required. Having a septic tank may require residents to limit their water use, as the tanks are sized according to the number of occupants in the home. These systems, which rely on microbial action, are also sensitive to hazardous chemicals (e.g., chlorine) or oil and grease, and disposal of

---

<sup>16</sup> Lu, C., G. Adamkiewicz, K.R. Attfield, M. Kapp, J.D. Spengler, L. Tao, and S.H. Xie. "Household Pesticide Contamination from Indoor Pest Control Applications in Urban Low-Income Public Housing Dwellings: A Community-Based Participatory Research." *Environmental Science and Technology* 47, no. 4 (2013): 2018–25.

<sup>17</sup> "Well Aware" website at <http://www.wellaware.ca/pages/TestYourWater.php>

large amounts of these wastes down the drain may cause the system to fail.<sup>18</sup> A failed septic system may lead to a backup of sewage into the home or the pooling of untreated wastewater around the tank. This in turn increases the risk of contamination of wells in the area via surface runoff.

Chemical contamination of private wells may also occur. For example, **nitrates** and **nitrites** from fertilizers or agricultural or human wastes may contaminate drinking water supplies, particularly shallow wells. These contaminants are particularly a concern for infants under six months of age who are fed formula reconstituted with tap water. Elevated concentrations of nitrates and nitrites can lead to methemoglobinemia in infants, a condition more commonly known as blue baby syndrome, which reduces the delivery of oxygen to the tissues.<sup>19</sup>

#### 4. Chemical hazards

A large number of chemicals can be detected in the home. Some— such as **volatile organic compounds or VOCs** – are measured mainly in air. Others are semi-volatile (for example many pesticides), with some of the chemical volatilized to air and some deposited on surfaces in the home or in house dust. House dust also collects non-volatile chemicals, including metals such as lead.<sup>20</sup> Some chemicals in the home originate from outdoor sources, such as traffic or industrial emissions. These pollutants infiltrate indoors in the form of gases or airborne particles. Other outdoor pollutants may be tracked in by people or pets.

Many chemicals in the home are from sources located indoors, such as building materials, furniture, and household consumer products, combustion appliances and smoking. Ventilation through opening windows or with a HVAC (Heating Air Conditioning Ventilation) system can reduce levels of pollutants produced indoors, especially VOCs. Vacuuming with a high-quality vacuum cleaner, wet mopping and/or dusting with a damp cloth can reduce exposures via house dust. The most effective means of limiting exposure is removal of the source (e.g., not smoking indoors, avoiding fragranced products).

Various sources of chemicals indoors, as well as moisture, that can lead to mould growth, and radon (see section 5: Radiation Hazards) are illustrated in Figure 2.

The sections that follow provide information on some of the most investigated chemical contaminants found in the indoor environment, together with information on exposure and suspected or known health effects. This overview is far from

---

<sup>18</sup> CDC and HUD 2006 (footnote 3).

<sup>19</sup> Health Canada. “Guidelines for Canadian Drinking Water Quality, Guideline Technical Document: Nitrate and Nitrite.” Health Canada, 2013. [http://www.hc-sc.gc.ca/ewh-semt/pubs/water-eau/nitrate\\_nitrite/index-eng.php](http://www.hc-sc.gc.ca/ewh-semt/pubs/water-eau/nitrate_nitrite/index-eng.php).

<sup>20</sup> Roberts, John W., Lance A. Wallace, David E. Camann, Philip Dickey, Steven G. Gilbert, Robert G. Lewis, and Tim K. Takaro. “Monitoring and Reducing Exposure of Infants to Pollutants in House Dust.” In *Reviews of Environmental Contamination and Toxicology Vol 201*, edited by David M. Whitacre, 201:1–39. Boston, MA: Springer US, 2009.

exhaustive, however. Only selected chemicals are discussed among the many released indoors from building materials, furnishings and the use of consumer products.

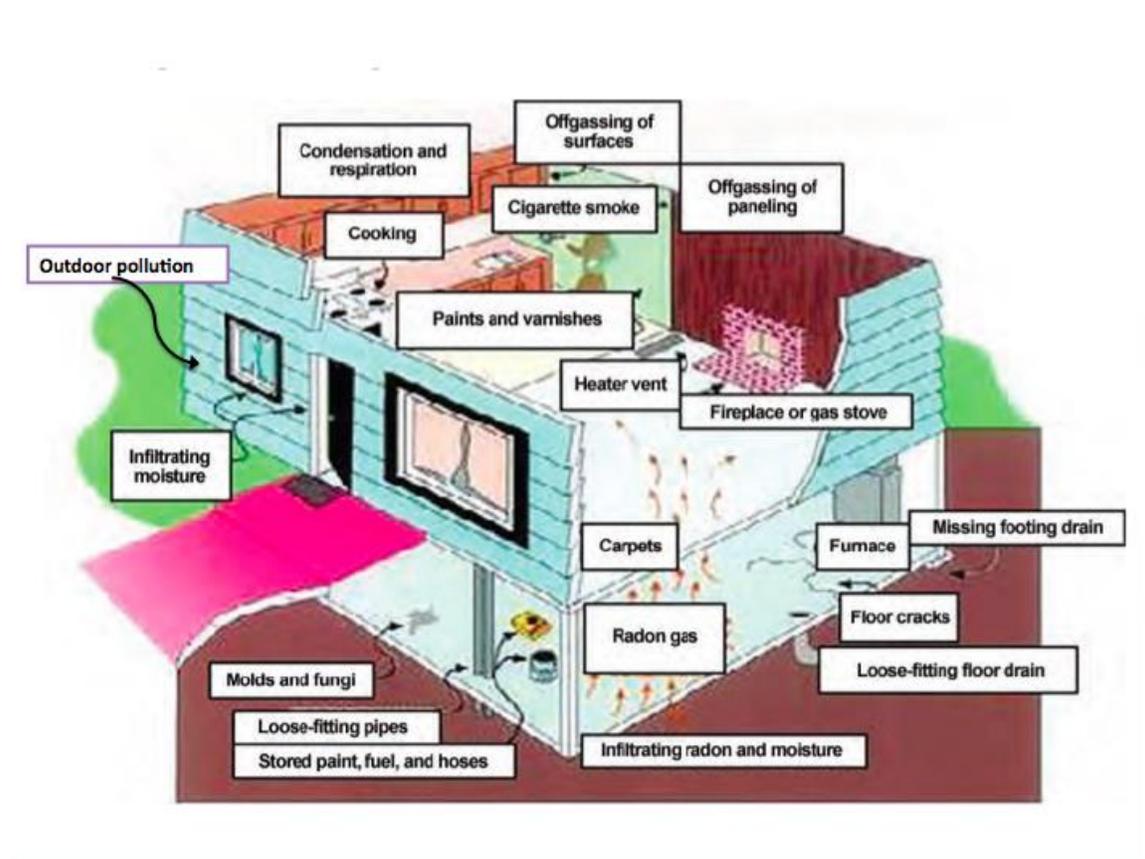


Figure 2: Sources of moisture and air pollutants in the home. Adapted from Centres for Disease Control and Prevention and U.S. Department of Housing and Urban Development. "Healthy Housing Reference Manual." Atlanta: US Department of Health and Human Services, 2006. Reproduced here with the Department's permission.

#### 4.1 Outdoor air pollution

Outdoor air pollution is a complex mixture of suspended particles of different sizes (coarse, fine and ultrafine) and gases – **ozone, nitrogen dioxide, sulfur dioxide, carbon monoxide**, and VOCs such as **benzene** or **toluene**. Contaminants in outdoor air can move indoors through open windows, via the ventilation system, or through cracks and other openings in the building. Fine and ultrafine particles, which may deposit deep in the lung, can cause damage both to the lung, and release chemicals from their surface into the blood stream. Outdoor air pollution increases the risk of cardiovascular disease and respiratory diseases including asthma. Approximately

7200 deaths each year have been attributed to air pollution in Canada, as estimated from levels of fine particulate matter measured in 2011.<sup>21</sup>

Different groups within a population are more vulnerable to air pollution – pregnant women, children and the elderly, individuals with pre-existing respiratory or cardiovascular disease, and people living in poverty.<sup>22</sup> Several factors may account for the link to poverty – for example greater traffic density and industrial emissions in low-income areas, housing that allows more infiltration of pollutants, and higher baseline rates of heart and respiratory disease in low-income populations.

Heat waves, particularly when combined with air pollution, increase the rates of illness and mortality from many chronic conditions (cardiovascular and respiratory disease, diabetes, kidney disease and others), in addition to causing heat exhaustion and heat stroke. People living in poverty and particularly the elderly in poor health are again at greater risk as they have less access to air-conditioned spaces or immediate medical care.<sup>23</sup>

#### 4.2 Environmental tobacco smoke

**Environmental tobacco smoke (ETS)**, also known as secondhand smoke, is a mixture of many chemicals in smoke released from a burning cigarette and smoke exhaled by a smoker. The health risks of exposure to ETS have been extensively documented since the 1970s.

Decreased birth weight and prematurity, fetal loss, and birth defects have all been associated with exposure to ETS during pregnancy. Prenatal ETS exposure has been associated with higher rates of sudden infant death syndrome, effects on neurodevelopment, increased risk of respiratory illness and possibly some childhood cancers.<sup>24</sup> Exposure to ETS in early childhood leads to more severe symptoms in asthmatic children and contributes to the development of the disease.<sup>25</sup>

---

<sup>21</sup> Stieb, DM, Judek, S, van Donkelaar, A, Martin, RV, Brand, et al (2015) Estimated Public Health Impacts of Changes in Concentrations of Fine Particle Air Pollution in Canada, 2000-2011. *Canadian Journal of Public Health*, 106.6 (Sep/Oct 2015): E362-E368.

<sup>22</sup> Sacks, J.D., L.W. Stanek, T.J. Luben, D.O. Johns, B.J. Buckley, J.S. Brown, and M. Ross. "Particulate Matter-Induced Health Effects: Who Is Susceptible?" *Environmental Health Perspectives* 119, no. 4 (2011): 446-54.

<sup>23</sup> Kravchenko, J., A.P. Abernethy, M. Fawzy, and H.K. Lyerly. "Minimization of Heatwave Morbidity and Mortality." *American Journal of Preventive Medicine* 44, no. 3 (2013): 274-82.

<sup>24</sup> Samet, Jonathan M., Gila I. Neta, and Sophia S. Wang. "Secondhand Smoke." In *Environmental Toxicants: Human Exposures and Their Health Effects*, edited by Morton Lippmann, 703-55, 2009.

<sup>25</sup> Dick, Smita, Emma Doust, Hilary Cowie, Jon G Ayres, and Steve Turner. "Associations between Environmental Exposures and Asthma Control and Exacerbations in Young Children: A Systematic Review." *BMJ Open* 4, no. 2 (February 1, 2014).

Dick, S, A Friend, K Dynes, F AlKandari, E Doust, H Cowie, J G Ayres, and S W Turner. "A Systematic Review of Associations between Environmental Exposures and Development of Asthma in Children Aged up to 9 Years." *BMJ Open* 4, no. 11 (November 1, 2014).

In adults ETS exposure increases the risk of lung cancer, and has been linked to other types of cancer as well. ETS contributes to respiratory disease, including asthma, and cardiovascular disease in adults, as well as premature death.<sup>26</sup>

The prevalence of smoking is generally higher among low-income populations, but other factors as well affect exposure to ETS in low-income housing. In a multi-unit building ETS exposure is not limited to the homes of smokers. ETS may infiltrate indoors from outside, where there is smoking nearby, or from hallways or adjoining units.<sup>27</sup> Restricting smoking in common areas of a multi-unit building (halls, elevators, laundry room) and adapting building design and ventilation to limit intake of ETS-contaminated air may contribute to reducing exposure.

### 4.3 Pesticides

Prior to 2000 **organophosphate (OP) pesticides** were widely used in the home for pest control. Because of the toxicity of these substances, their uses have been restricted and **pyrethroids** are now more commonly found in household pest control products.<sup>28</sup> Prenatal and early childhood exposures to OP pesticides have been linked to adverse and long-term health effects, including smaller birth size and decreased performance on a range of mental and motor ability tests.<sup>29</sup>

Although pyrethroids are generally considered to have low toxicity in comparison to OP pesticides, there is nonetheless some evidence for associations between environmental exposures and adverse effects on child development and on male reproduction.<sup>30</sup> Children living in urban low-income housing typically have higher pyrethroid exposures, likely reflecting the greater use of pesticides in the home in addition to dietary exposures from the use of these chemicals on food crops.<sup>31</sup>

### 4.4 Carbon monoxide

**Carbon monoxide (CO)** is a toxic, odourless gas produced through combustion. Breathing CO reduces the blood's capacity to carry and deliver oxygen to tissues. At

---

<sup>26</sup> Samet et al, 2009 (see footnote 24)

<sup>27</sup> Kraev, T.A., G. Adamkiewicz, S.K. Hammond, and J.D. Spengler. "Indoor Concentrations of Nicotine in Low-Income, Multi-Unit Housing: Associations with Smoking Behaviours and Housing Characteristics." *Tobacco Control* 18, no. 6 (2009): 438–44.

<sup>28</sup> van Balen, Erna, Marcelo Wolansky, and Tom Kosatsky. "Increasing Use of Pyrethroids in Canadian Households: Should We BE Concerned?" *Canadian Journal of Public Health* 103, no. 6 (2012): e404–7; Oulhote, Y., and M.F. Bouchard. "Urinary Metabolites of Organophosphate and Pyrethroid Pesticides and Behavioral Problems in Canadian Children." *Environmental Health Perspectives* 121, no. 11–12 (2013): 1378–84.

<sup>29</sup> Rauh, V.A., M.K. Horton, R.L. Miller, R.M. Whyatt, and F. Perera. "Neonatology and the Environment: Early Exposure to Airborne Environmental Toxicants." *NeoReviews* 11, no. 7 (2010): e363–69.

<sup>30</sup> Saillenfait, A.-M., D. Ndiaye, and J.-P. Sabaté. "Pyrethroids: Exposure and Health Effects - An Update." *International Journal of Hygiene and Environmental Health* 218, no. 3 (2015): 281– 292.

<sup>31</sup> Lu, C., G. Adamkiewicz, K.R. Attfield, M. Kapp, J.D. Spengler, L. Tao, and S.H. Xie. "Household Pesticide Contamination from Indoor Pest Control Applications in Urban Low-Income Public Housing Dwellings: A Community-Based Participatory Research." *Environmental Science and Technology* 47, no. 4 (2013): 2018–25.

lower concentrations of CO, people may experience flu-like symptoms. Very high levels of CO exposure can cause convulsions, coma and death.<sup>32</sup>

CO poisoning incidents most frequently occur when a furnace or gas stove malfunctions, resulting in indoor release of the exhaust gases. The use of unvented kerosene heaters indoors has also caused CO poisoning.

Carbon monoxide detectors trigger an alarm when concentrations of CO are approaching dangerous levels. In Ontario, since 2014, installing CO detectors is required near sleeping areas in all single-dwelling homes in which there are fuel-burning heating systems or appliances, or attached garages. In multi-unit buildings CO detectors are required in suites that contain a fuel-burning appliance or that are adjacent to a service room with a fuel-burning appliance or a parking or storage garage.<sup>33</sup>

Long-term exposure to lower levels of CO in indoor air, while not resulting in immediate life-threatening symptoms, may also reduce oxygen delivery to the tissues<sup>2</sup>. International guidelines, in fact, recommend concentration limits that are well below levels that trigger a CO detector alarm, based on the health impacts of CO exposure in individuals with coronary disease.<sup>34</sup> For this reason CO detectors are not considered a substitute for good maintenance of combustion equipment.

#### 4.5 Volatile Organic Compounds (VOCs)

Indoor sources of **volatile organic compounds (VOCs)** include smoking, building materials, furniture, cleaning products, fragrances, “air fresheners”, glues and renovation and home repair materials, as well as moulds. Infiltration from outdoor air may be important for some VOCs, especially where homes are located close to industrial sources or busy roadways.<sup>35</sup> Because of the many indoor sources, levels of most VOCs indoors are two to three times higher (or more) than outdoors.<sup>36</sup>

Many VOCs are irritants, evidenced by symptoms such as nose and throat irritation, headache, dizziness, and others.<sup>37</sup> Ensuring good ventilation during and after the use of VOC-containing products, such as strong cleaners, paints or other renovation materials, can reduce or prevent these symptoms.

---

<sup>32</sup> Health Canada: [http://www.hc-sc.gc.ca/ewh-semt/pubs/air/carbon\\_mono/fact-info-eng.php](http://www.hc-sc.gc.ca/ewh-semt/pubs/air/carbon_mono/fact-info-eng.php)

<sup>33</sup> <http://www.ontario.ca/laws/regulation/r14194>

<sup>34</sup> Health Canada: <http://healthycanadians.gc.ca/publications/healthy-living-vie-saine/carbon-monoxide-carbone/index-eng.php>

<sup>35</sup> Kwon, J., C.P. Weisel, B.J. Turpin, J. Zhang, L.R. Korn, M.T. Morandi, T.H. Stock, and S. Colome. “Source Proximity and Outdoor-Residential VOC Concentrations: Results from the RIOPA Study.” *Environmental Science and Technology* 40, no. 13 (2006): 4074–82.

<sup>36</sup> Health Canada. “Edmonton Indoor Air Quality Study (2010: Volatile Organic Compounds (VOCs) Data Summary.” Health Canada, 2013.

<sup>37</sup> Mølhave, Lars. “Volatile Organic Compounds and Sick Building Syndrome.” In *Environmental Toxicants: Human Exposures and Their Health Effects*, edited by Morton Lippmann, 3rd ed. Hoboken, New Jersey, USA: John Wiley & Sons, Inc, 2009.

Some VOCs are used as fragrances in products such as “air fresheners”, soaps, shampoos, detergents, dryer sheets, and household cleaners. Although fragrances are added to products to make them more appealing, they are also irritating to sensitive individuals, causing, for example, watery and itchy eyes or worsening of asthma symptoms.<sup>38</sup>

Individual VOCs have been associated with adverse health effects in animal and occupational studies. For example, studies in industrial settings have shown that **benzene** increases the risk of leukemia<sup>39</sup>. Workers exposed to **toluene** have lower performance in neurological tests<sup>40</sup>. However, investigations into the health effects of benzene, toluene and other specific VOCs in homes, where levels of exposure are typically 1000 times lower, are limited in number, and there is little consistency in findings. One exception is **formaldehyde**, which has been more frequently studied. Much of the research on formaldehyde supports an association between exposure and asthma in children.<sup>41</sup>

Formaldehyde is classified as a known carcinogen, based in part on occupational studies in which workers were highly-exposed.<sup>42</sup> The potential of formaldehyde to cause cancer at low levels is more controversial, resulting in a wide spread of guideline values and risk estimates from different public health organizations.<sup>43</sup>

Many individuals experience hyper-sensitivity to VOCs and other chemicals, developing an array of non-specific symptoms such as headache, fatigue, loss of concentration and memory impairment, triggered by multiple chemicals. An estimated 2.4% of the Canadian population, aged 12 years or older has been diagnosed with multiple chemical sensitivity (MCS) – about 800,000 individuals.<sup>44</sup> The symptoms of MCS occur at exposure levels that do not appear to affect most people, although the hyper-sensitivity may have begun with an initial high-exposure

---

<sup>38</sup> CPCHE fact sheet:

[http://www.healthyenvironmentforkids.ca/sites/healthyenvironmentforkids.ca/files/CPCHE\\_FactsFragrancesEN.pdf](http://www.healthyenvironmentforkids.ca/sites/healthyenvironmentforkids.ca/files/CPCHE_FactsFragrancesEN.pdf)

<sup>39</sup> Health Canada: <http://healthycanadians.gc.ca/publications/healthy-living-vie-saine/benzene/index-eng.php>

<sup>40</sup> Health Canada: <http://healthycanadians.gc.ca/publications/healthy-living-vie-saine/toluene/index-eng.php>

<sup>41</sup> McGwin, Gerald, Jeffrey Lienert, and John I Kennedy. “Formaldehyde Exposure and Asthma in Children: A Systematic Review.” *Environmental Health Perspectives* 118, no. 3 (March 2010): 313–17.

<sup>42</sup> International Agency for Research on Cancer:

<http://monographs.iarc.fr/ENG/Monographs/vol100F/mono100F-29.pdf>

<sup>43</sup> See for example World Health Organization:

[http://www.who.int/indoorair/publications/9789289002134/en/;](http://www.who.int/indoorair/publications/9789289002134/en/)

Health Canada:

[http://healthycanadians.gc.ca/publications/healthy-living-vie-saine/formaldehyde/index-eng.php;](http://healthycanadians.gc.ca/publications/healthy-living-vie-saine/formaldehyde/index-eng.php)

and California Office of Environmental Health Hazard Assessment:

[http://www.oehha.ca.gov/air/hot\\_spots/2009/AppendixB.pdf](http://www.oehha.ca.gov/air/hot_spots/2009/AppendixB.pdf) p. B-344.

<sup>44</sup> Lavergne, M. Ruth, Donald C. Cole, Kathleen Kerr, and Lynn M. Marshall. “Functional Impairment in Chronic Fatigue Syndrome, Fibromyalgia, and Multiple Chemical Sensitivity.” *Canadian Family Physician* 56, no. 2 (February 1, 2010): e57–65.

incident.<sup>45</sup> Research exploring the underlying biological causes of this illness is at present limited. Nonetheless, for people with this condition, knowledge of potential sources of VOCs in their homes is essential to managing their health.

#### 4.6 Flame Retardants

Flame retardants are chemicals added to textiles (rugs, upholstery, polyurethane foam), building materials and electronic equipment. They are easily released from products and tend to accumulate in both indoor and outdoor environments. Between 1970 and 2004 a commercial mixture of **polybrominated diphenyl ethers (PBDEs)** was the most widely-used flame retardant product, especially in furniture. After 2004 its use was phased out through international restrictions and bans.<sup>46</sup>

Much of the health research has focussed on the effects on the developing brain in children exposed in the womb to PBDEs transferred from their mothers' blood. The association between adverse neurological effects and prenatal exposure to PBDEs has been demonstrated in animal studies and is strongly supported by recent evidence from human population studies.<sup>47,48,49</sup>

Exposure to PBDEs, while reduced over the last decade, is ongoing, reflecting continued use of older products, such as couches. This is of particular concern for lower-income families, who may more often buy furniture second-hand and keep it for longer periods.<sup>50</sup> As PBDEs tend to accumulate in dust, regular dusting, vacuuming and handwashing is important for reducing exposure, especially in the most vulnerable individuals – pregnant women and children.

#### 4.7 Phthalates (plasticizers and fragrances)

**Phthalates** are a large group of chemical additives commonly used in personal care products, fragrances, and as additives in various plastics and vinyl flooring to

---

<sup>45</sup> Genuis, S.J. "Sensitivity-Related Illness: The Escalating Pandemic of Allergy, Food Intolerance and Chemical Sensitivity." *Science of the Total Environment* 408, no. 24 (2010): 6047–61.

<sup>46</sup> Betts, Kellyn. "Hand-Me Down Hazard, Flame Retardants in Discarded Foam Products." *Environmental Health Perspectives* 123, no. 3 (March 2015): A56–63.

<sup>47</sup> Herbstman, Julie B, Andreas Sjödin, Matthew Kurzton, Sally A Lederman, Richard S Jones, Virginia Rauh, Larry L Needham, et al. "Prenatal Exposure to PBDEs and Neurodevelopment." *Environmental Health Perspectives* 118, no. 5 (May 2010): 712–19.

<sup>48</sup> Eskenazi, Brenda, Jonathan Chevrier, Stephen A Rauch, Katherine Kogut, Kim G Harley, Caroline Johnson, Celina Trujillo, Andreas Sjödin, and Asa Bradman. "In Utero and Childhood Polybrominated Diphenyl Ether (PBDE) Exposures and Neurodevelopment in the CHAMACOS Study." *Environmental Health Perspectives* 121, no. 2 (February 2013): 257–62.

<sup>49</sup> Chen, Aimin, Kimberly Yolton, Stephen A Rauch, Glenys M Webster, Richard Hornung, Andreas Sjödin, Kim N Dietrich, and Bruce P Lanphear. "Prenatal Polybrominated Diphenyl Ether Exposures and Neurodevelopment in U.S. Children through 5 Years of Age: The HOME Study." *Environmental Health Perspectives* 122, no. 8 (August 2014): 856–62.

<sup>50</sup> Betts 2015 (see footnote 46).

increase flexibility and durability. As with PBDEs, phthalates are easily released from the products into the environment – to air, to dust or to food.<sup>51</sup>

Animal studies using high doses of phthalates have demonstrated adverse effects on reproduction, especially in males, on brain development in animals exposed prenatally, and on the immune system. Evidence in human population studies, suggest that these types of health effects could occur in humans as well, at current exposure levels. For example, some research has indicated a possible association between polyvinyl chloride products in the home, such as vinyl flooring, and asthma and allergies in children.<sup>52</sup> However, larger long-term investigations would be required to conclude with confidence that the effects observed are caused by exposure to phthalates.<sup>53,54,55</sup>

#### 4.8 Lead

**Lead** is one of the most extensively investigated toxic substances, with studies motivated first by cases of acute lead poisoning in small children and later by observations of long-term adverse effects on children’s mental and behavioural development. Efforts to reduce environmental lead sources, in particular reducing lead in interior paint and phasing out leaded gasoline, have resulted in a steep decline in exposure since the 1970s.

Exposure to lead in young children can reduce IQ and affect other mental abilities and behaviours.<sup>56</sup> Cases of death or severe brain damage from lead poisoning have become rare, but exposure to lead in the home continues. Lead levels measured in Canadian children (aged 3 to 5 years) are generally less than 2 micrograms per deciliter ( $\mu\text{g}/\text{dL}$ ) of blood, with average levels being approximately 1  $\mu\text{g}/\text{dL}$ .<sup>57</sup> Although these exposures are approximately ten times less than typical levels in the 1970s, the health studies have indicated that there is no safe level of lead – in other words there is no threshold level below which adverse effects would not occur. Moreover, some evidence indicates that exposure over a lifetime may lead to

---

<sup>51</sup> Lyche, J.L., A.C. Gutleb, Å. Bergman, G.S. Eriksen, A.J. Murk, E. Ropstad, M. Saunders, and J.U. Skaare. “Reproductive and Developmental Toxicity of Phthalates.” *Journal of Toxicology and Environmental Health - Part B: Critical Reviews* 12, no. 4 (2009): 225–49

<sup>52</sup> Jaakkola, Jouni JK, and Trudy L Knight. “The Role of Exposure to Phthalates from Polyvinyl Chloride Products in the Development of Asthma and Allergies: A Systematic Review and Meta-Analysis.” *Environmental Health Perspectives* 116, no. 7 (July 2008): 845–53.

<sup>53</sup> Martino-Andrade, A.J., and I. Chahoud. “Reproductive Toxicity of Phthalate Esters.” *Molecular Nutrition and Food Research* 54, no. 1 (2010): 148–57;

<sup>54</sup> Ejaredar, M., E.C. Nyanza, K. Ten Eycke, and D. Dewey. “Phthalate Exposure and Childrens Neurodevelopment: A Systematic Review.” *Environmental Research* 142 (2015): 51–60;

<sup>55</sup> North, M.L., T.K. Takaro, M.L. Diamond, and A.K. Ellis. “Effects of Phthalates on the Development and Expression of Allergic Disease and Asthma.” *Annals of Allergy, Asthma and Immunology* 112, no. 6 (2014): 496–502.

<sup>56</sup> Weitzman, M., A. Baten, D.G. Rosenthal, R. Hoshino, E. Tohn, and D.E. Jacobs. “Housing and Child Health.” *Current Problems in Pediatric and Adolescent Health Care* 43, no. 8 (2013): 187–224. doi:10.1016/j.cppeds.2013.06.001.

<sup>57</sup> Health Canada <http://www.hc-sc.gc.ca/ewh-semt/pubs/contaminants/chms-ecms-cycle3/index-eng.php#s10d>

neurological effects in older adults as well as increased risk of cardiovascular and kidney disease.<sup>58,59</sup>

Older homes tend to have higher levels of lead due to the higher percentages of lead in older paints. Another source is lead in soil tracked into the home, with much of the soil contamination from either a history of leaded paint use on the building exterior or dating back to vehicle emissions prior to the phase-out of leaded gasoline. Lead is also one of the many contaminants in secondhand smoke.<sup>60</sup>

Another possible source of exposure is drinking water. Before 1950 lead pipes were commonly used in water service lines (pipe bringing water into the home from the municipal system) and in plumbing systems in homes (but not in apartment buildings of more than six units).<sup>61</sup> As well, until the early 1990s, lead solder was used to join copper pipes. Under certain conditions this lead can leach out into the drinking water (more so in the case of lead pipes than lead solder), particularly if the water has not been run for several hours. Municipalities are responsible for the replacement of lead service lines. Plumbing codes no longer allow use of lead pipes or lead solder<sup>62</sup>, although both are still found in some older homes.

#### 4.9 Asbestos

**Asbestos** refers to a group of naturally-occurring silicate mineral fibers, widely-used in products prior to 1970 as a heat and noise insulating material and for fire-proofing. In some homes, asbestos fibers may be found in vermiculite insulation (Zonolite) installed before 1990. Uses have steadily been restricted or banned since 1970 because of the toxicity of the fibers, and particularly their potential to cause cancer.<sup>63</sup>

Asbestos fibers when airborne may be breathed in and deposited in the lung. The effects of long-term exposure include asbestosis (damage to the lungs with associated difficulty in breathing), lung cancer, and mesothelioma (a rare cancer of the protective lining of internal organs). The highest exposures to asbestos fibers and consequently the highest rates of asbestos-related disease occur among those

---

<sup>58</sup> Grossman, Elizabeth. "Time after Time, Environmental Influences on the Aging Brain." *Environmental Health Perspectives* 122, no. 9 (September 2014): A238-43;

<sup>59</sup> Cooper, K, L Marshall, L Vanderlinden, and F Ursitti. "Early Exposures to Hazardous Chemicals/Pollution and Associations with Chronic Disease: A Scoping Review. A Report from the Canadian Environmental Law Association, the Ontario College of Family Physicians and the Environmental Health Institute of Canada,," 2011.

<sup>60</sup> Weitzman et al., 2013 (see footnote 56).

<sup>61</sup> City of Toronto:

<http://www1.toronto.ca/wps/portal/contentonly?vgnextoid=35bcfe4eda8ae310VgnVCM10000071d60f89RCRD>

<sup>62</sup> Health Canada: <http://www.hc-sc.gc.ca/ewh-semt/pubs/water-eau/lead-plomb-eng.php>

<sup>63</sup> Canadian Centre for Occupational Health and Safety

:<http://www.ccohs.ca/oshanswers/chemicals/asbestos/whatis.html>

exposed occupationally (for example, miners, construction workers, maintenance workers in contact with asbestos-containing materials).<sup>64,65</sup>

Asbestos-containing materials, when undisturbed and in good condition, can be left in place as few fibers are released to the air. If, however, the materials are damaged or would be disturbed by renovations health agencies (for example Health Canada and the US Consumer Product Safety Commission) recommend that these materials be sealed or removed and disposed of, generally by an asbestos remediation professional.

## 5. Radiation hazards

**Electromagnetic radiation (EMR)** is classified into (i) ionizing radiation, including x-rays, and radioactive decay from such compounds as uranium and radon, and (ii) non-ionizing radiation. Non-ionizing radiation spans a wide range of lower frequencies that carry much less energy. Visible light, as well as radiation emitted from radio and TV broadcasting, cell phones, wireless telecommunication systems and power transmission and distribution lines are examples of non-ionizing EMR.

The evidence for health effects from ionizing radiation is well-established. Investigation of the health effects of non-ionizing radiation is relatively recent and much more subject to debate among scientists and health authorities.

### 5.1 Radon

Radon is a naturally-occurring radioactive gas that is a product of the radioactive decay of uranium in rock, soil and groundwater. Radon migrates through the soil and can then enter into buildings through cracks and other openings in the foundation. Indoors, radon may accumulate to hazardous levels. When someone breathes in radon he or she is exposed to ionizing radiation that can cause DNA damage. Exposure to radon increases the risk of developing lung cancer, particularly in smokers, or where ETS is present. Health Canada estimates that 16 % of lung cancer deaths in Canada are attributable to radon exposure.<sup>66 67</sup>

Testing kits for radon, widely available in hardware stores, can be used to measure radon levels in the home. Health Canada currently recommends taking action to lower radon levels if the concentration in the living area exceeds 200 Bq/m<sup>3</sup>, averaged over a year.<sup>68</sup> A common solution consists of the installation by a certified professional of a pipe that draws air from below the concrete slab of the basement floor and vents it through an exhaust outlet, equipped with a fan, at the side or on

---

<sup>64</sup> Health Canada: <http://www.healthycanadians.gc.ca/healthy-living-vie-saine/environnement-environnement/air/contaminants/asbestos-amiante-eng.php#a2>

<sup>65</sup> US Consumer Product Safety Commission: <http://www.cpsc.gov/en/Safety-Education/Safety-Guides/Home/Asbestos-In-The-Home/>

<sup>66</sup> <http://hc-sc.gc.ca/ewh-semt/radiation/radon/index-eng.php>

<sup>67</sup> <http://www.healthyenvironmentforkids.ca/content/reduce-radon>

<sup>68</sup> Bq/m<sup>3</sup> refers to Becquerels per cubic meter of air, with the Becquerel being a unit of measure of radioactivity

the roof of the building. This system can remove more than 90 percent of the radon that would otherwise enter the home.

## 5.2 Non-ionizing electromagnetic radiation

Most of the research on non-ionizing EMR, at exposure levels experienced by the general population, has focused on cancer. Initially the interest was in extremely low frequency magnetic fields from power lines, following a report in 1979 of an association between these fields and childhood leukemia. In later years, as the use of cell phones became ubiquitous, researchers investigated the relationship between exposure to radio frequencies emitted from cell phones and certain types of brain cancer.

In a review in 2002 the International Agency for Research on Cancer (IARC) concluded that extremely low frequency magnetic fields are possibly carcinogenic to humans. In 2013 the Agency concluded that radiofrequency electromagnetic fields are possibly carcinogenic to humans. These conclusions acknowledge the positive findings in some studies of an association between exposure to EMR and different types of cancer, while indicating that the evidence is not strong enough to conclude that there is a causal link.<sup>69,70</sup>

Concern with other possible health effects of non-ionizing EMR has also grown in recent years. An increasing number of individuals report a range of symptoms (headaches, impaired memory and concentration, sleep disorders and others) that they associate with common exposures to different EMR-generating devices in their homes and workplaces. This condition is known as electro hypersensitivity. Knowledge of the biological basis for the illness is at present very limited. Nonetheless, individuals with electro hypersensitivity find that reducing their exposure to EMR, either across a range of frequencies or by targeting particular devices, can lead to an improvement in their symptoms.<sup>71</sup>

## 6. Conclusion

This overview has described how exposure to different contaminants in the home environment can affect health, and has largely considered these hazards separately. Yet people are exposed to multiple hazards in their homes, workplaces, while commuting, or out in their neighbourhoods. Their health depends on cumulative effects, especially when different hazards target the same organs or biological processes, such as the developing brain, or the respiratory system.

---

<sup>69</sup> IARC. "IARC Monographs on the Evaluation of Carcinogenic Risks to Humans: Non-Ionizing Radiation, Part 1: Static and Extremely Low-Frequency (ELF) Electric and Magnetic Fields, Volume 80." International Agency for Research on Cancer, 2002.

<sup>70</sup> IARC "IARC Monographs on the Evaluation of Carcinogenic Risks to Humans: Non-Ionizing Radiation, Part II. Radiofrequency Electromagnetic Fields." International Agency for Research on Cancer, 2013.

<sup>71</sup> Genuis, S.J., and C.T. Lipp. "Electromagnetic Hypersensitivity: Fact or Fiction?" *Science of the Total Environment* 414 (2012): 103–12. doi:10.1016/j.scitotenv.2011.11.008.

Other factors, including stress, diet, and health status also modify the impact of environmental hazards on an individual's health. The complexity of the interaction of real exposures and other health factors is one reason why human population studies are so challenging to carry out, and why the findings from these studies may be far from clear and definitive. It is often difficult to separate the effects of one exposure from another or detect small effects that are masked by other factors.

Yet, in spite of the challenges, even small effects from environmental hazards have been demonstrated through human studies. For example, small decreases in IQ from exposure to lead or PBDEs may not be apparent looking at a few individuals, given the large natural variability in IQ in a population, but become evident in a study with many participants.

Moreover, small effects are not trivial. They may impact the health of an individual throughout his or her lifetime, especially if the exposure occurs during pregnancy, infancy, or in early childhood.<sup>72</sup> Moreover, small increases in risk for individuals may collectively have a large impact on public health when much of a population (or a group within the population) is exposed<sup>73</sup>.

All of the environmental hazards described in this background paper can be found in homes across Canada, regardless of income level. Yet it is clear that low-income renters, on average, experience greater health risks, whether the hazard is mould, pests, pesticides, outdoor air pollution, secondhand smoke, lead, flame retardants, or other toxic substances found indoors. These risks may also be amplified by the physical and emotional stress of living in substandard housing. By ensuring healthier housing we contribute to a healthier population and, importantly, help children get a better start towards lifelong health.

---

<sup>72</sup> Cooper et al., 2011 (see footnote 59)

<sup>73</sup> Lanphear et al., 2014. Little Things Matter: The Impact of Toxins on the Developing Brain (video). <http://www.healthyenvironmentforkids.ca/video/new-video-little-things-matter-impact-toxins-developing-brain>