This presentation provides some of the basic information needed to understand how food contamination affects children. It stresses the ways children from preconception through adolescence are different from adults in their exposure to food contaminants.
Children and Food Safety

LEARNING OBJECTIVES

After this presentation, individuals will understand:

❖ Major foodborne risks for
  ▪ Embryo / foetus
  ▪ Breast and bottle-fed infants
  ▪ Children and infants receiving complementary foods

❖ How to reduce food contamination during
  ▪ Production
  ▪ Storage
  ▪ Preparation

<<READ SLIDE>>
Definition of foodborne diseases: Foodborne diseases are defined as diseases, usually either infectious or toxic in nature, caused by agents that enter the body through the ingestion of food. Every person is at risk of foodborne diseases.

Unfortunately, data on the incidence and severity of foodborne diseases in the general population are limited in most countries. Where such data are collected through surveillance programmes, most cases of foodborne diseases are not reported, either because medical treatment is not sought or, when treatment is sought, specimens are not taken to allow diagnostic tests to identify the foodborne pathogen. Also, certain pathogens transmitted via food may also be spread through water or by person-to-person contact, and this may obscure the role of food as a vehicle for transmission. In addition, some foodborne disease is caused by hitherto unknown pathogens, and thus cannot be diagnosed. Many pathogens, such as Campylobacter jejuni, Escherichia coli O157:H7 and Cyclospora cayetanensis, were not recognized as causes of foodborne disease twenty years ago. Nowadays, new pathogens are being recognized as a cause of foodborne disease.

Foodborne diseases that are nationally reportable in certain developed countries include typhoid fever, cholera, hepatitis A, *E. coli* O157:H7 infection, haemolytic uraemic syndrome, salmonellosis, and shigellosis. Reporting requirements are stipulated by local and national regulations. In developing countries (excluding China), foodborne pathogenic microorganisms are estimated to cause up to 70% of the roughly 1.5 billion annual episodes of diarrhoea, and a related 1.8 million deaths in children under the age of five (Dr. G. Moy, WHO, personal communication). In the United States it is estimated that 76 million illnesses, 325,000 hospitalizations and 5000 deaths result each year from foodborne diseases. While the figure for morbidity suggests that one in three persons becomes ill each year, foodborne disease is expected to be more prevalent among the young.
References:
In 2006 WHO launched a new initiative to estimate the global burden of foodborne diseases. As part of this initiative, WHO established the Foodborne Disease Burden Epidemiology Reference Group. They are charged with estimating the global burden of foodborne disease, using DALYs (disability adjusted life years).

Reference:
Children have unique exposure pathways. They can be exposed \textit{in utero} to toxic environmental agents that cross the placenta. Such exposures can be biological (viral, bacterial, parasitic) or chemical (pesticides, toxins). They can also be exposed to pollutants that pass into their mother’s milk. Neither of these routes of exposure occur in adults or older children.

Children also have pathways of exposure that differ from those of adults due to their size and developmental stage. For example, young children engage in normal exploratory behaviours including hand-to-mouth and object-to-mouth behaviours, and non-nutritive ingestion which may dramatically increase exposure over that in adults.

The amount of food that children consume per kilogram of body weight is higher than that of the adult because children not only need to maintain homeostasis, as adults do, but are growing. The average infant consumes 5 oz. of formula per kilogram of body weight (for the average male adult, this is equivalent to drinking 30 12 oz. cans of liquid a day.) If the food or liquid contains a contaminant, children may receive more of it relative to their size than adults.

In addition, children consume different types of food. The diet of many newborn babies is exclusively breast milk. The diet of children usually contains more milk products and certain fruits and vegetables than the typical adult diet.

References:


The agents responsible for foodborne disease include viruses, bacteria, protozoa, parasites, and prions, as well as a wide range of chemicals, including toxins, pesticides, persistent organic pollutants (POPs), heavy metals, food additives, and any other chemical that may enter food. The adverse health effects of foodborne diseases range from mild gastroenteritis (including diarrhoea and vomiting) to life-threatening neurological, renal or hepatic syndromes, congenital anomalies and cancer. The risks posed by the presence of microorganisms and chemicals in the food supply are of concern worldwide. However, consumers’ judgment of hazards and perception of food safety risks are often at variance with those of the scientific community. Consumers’ perceptions in particular are shaped by a number of factors, including personal experience, access to information about food safety, trust in sources of information, and baseline food safety risk levels. Hence, while the public may be concerned about food additives and new technologies, they may fail to recognize the major risks resulting from food contaminated by pathogenic microorganisms.

References:
We will begin with viruses because they are thought to be the cause of most foodborne diseases, both in developing and industrialized countries.

<<READ SLIDE>>

Reference:
Viruses are considered the most common cause of infectious gastroenteritis, but except for rotaviruses, they are rarely identified. Hepatitis A and gastroenteritis viruses, such as rotaviruses, Norwalk-like viruses, astroviruses, and other caliciviruses are more often transmitted via food than other viruses. All foodborne viruses are shed in faeces and infect by being ingested.

The main symptoms of viral gastroenteritis are watery diarrhoea and vomiting. Patients may also have headache, fever and abdominal cramps. Symptoms occur 1 or 2 days after infection and last for 1–10 days. People with viral gastroenteritis almost always recover without long-term problems. However gastroenteritis can be serious for infants and young children, who are at risk of rapid dehydration from loss of fluids through vomiting or diarrhoea.

Food may be contaminated by food handlers who have viral gastroenteritis, especially if their personal hygiene is poor. Raw and undercooked shellfish grown in polluted waters are also an important vehicle for viral gastroenteritis.

Rotavirus infection is the most common cause of severe viral diarrhoea in infants and young children under 5 years old, resulting in the hospitalization of approximately 55 000 children each year in the United States. The incubation period for rotavirus disease is approximately 2 days, followed by vomiting and watery diarrhoea for 3–8 days. The primary mode of transmission is faecal–oral. The virus is stable in the environment, and transmission occurs through ingestion of contaminated water or food and contact with contaminated surfaces.

Reference:
Breast milk may be a source of viral infection in nursing infants whose mothers have acquired HIV or cytomegalovirus infections. Mother-to-child transmission of HIV can occur in utero, at delivery, or after birth through breastfeeding. Data from various studies estimate transmission rates, without antiretroviral intervention, of 15–25% in the absence of breastfeeding, 20–35% if there is breastfeeding up to 6 months, and 30–45% if breastfeeding is continued for 18–24 months.

The fact that HIV can be transmitted through breast milk should not undermine efforts to support breastfeeding for most infants, as their health and survival are greatly improved by breastfeeding.

Policies and strategies are evolving as more evidence becomes available from research, but more needs to be known about the factors that influence transmission rates and the risks associated with alternative feeding strategies. For women who know they are HIV-positive and where infant mortality is high, exclusive breastfeeding may still result in fewer infant deaths than feeding breast-milk substitutes. A WHO Technical Consultation recommended the following approaches to prevention of mother-to-child transmission:

• When replacement feeding is acceptable, feasible, affordable, sustainable and safe, avoidance of all breastfeeding by HIV-infected mothers is recommended. Otherwise, exclusive breastfeeding is recommended during the first months of life.

• To minimize HIV transmission risk, breastfeeding should be discontinued as soon as feasible, taking into account local circumstances, the individual woman’s situation and the risks of replacement feeding (including infections other than HIV and malnutrition).

• When HIV-infected mothers choose not to breastfeed from birth or stop breastfeeding later, they should be provided with specific guidance and support for at least the first 2 years of the child’s life to ensure adequate replacement feeding. Programmes should strive to improve conditions to make replacement feeding safer for HIV-infected mothers and families.

Countries should have in place a comprehensive national infant and young child feeding policy which includes information on HIV and infant feeding. Such a policy should lead to guidelines for health workers on how to protect, promote and support breastfeeding in the general population, while giving adequate support to HIV-positive women to enable them to select the best feeding option for themselves and their babies. The policy and guidelines should be based on the local situation, including an assessment of feeding options.

References:
• De Cock, Prevention of mother-to-child HIV transmission in resource-poor countries – translating research into


There are many bacteria that can cause foodborne diseases. Some are listed here.

**Reference:**

**L. monocytogenes** may cause a mild form of gastrointestinal illness in healthy adults. While such infections are uncommon and cause few or no symptoms in healthy people, they may be very serious for **pregnant women**. Women infected with *L. monocytogenes* during pregnancy may transmit the infection to the fetus, possibly leading to spontaneous abortion, fetal death, or subsequent visual, mental, or other health problems in the infant. The manifestations of listeriosis include septicemia, meningitis (or meningoencephalitis), encephalitis, and intrauterine or cervical infections in pregnant women, which may result in spontaneous abortion (2nd/3rd trimester) or stillbirth. The onset of the aforementioned disorders is usually preceded by influenza-like symptoms including persistent fever. It was reported that gastrointestinal symptoms such as nausea, vomiting, and diarrhea may precede more serious forms of listeriosis or may be the only symptoms expressed. Outbreak data show that the incubation period ranges from 2 to 6 weeks for the invasive disease. Listeriosis results in an estimated 2500 serious illnesses and 500 deaths in the United States each year. Pregnant women are about 20 times more likely than other adults to get sick from *L. monocytogenes*. The organism is typically found in raw meat, delicatessen products, including processed ready-to-eat meat products, soft unpasteurized cheeses, unpasteurized dairy products and chilled smoked seafood.

**References:**

- CDC on Listeriosis. Available at www.cdc.gov/ncidod/dbmd/diseaseinfo/listeriosis_g.htm (also available in Spanish) – accessed December 2009
E. coli O157:H7 is a cause of foodborne illness, and has rapidly become a major cause of bloody diarrhoea and acute renal failure. The infection can be fatal, especially in children. The largest outbreak recorded so far was in Japan in 1996 the cause of nearly 10 000 children becoming ill and five dying in more than eight outbreaks over a six-month period.

In children under 5 years of age (and the elderly), the infection can lead to the development of haemolytic uraemic syndrome. Between 2% and 7% of infections in the United States lead to this complication. The illness is characterized by severe cramping (abdominal pain) and diarrhea which is initially watery but becomes grossly bloody. Occasionally vomiting occurs. Fever is either low-grade or absent. The illness is usually self-limited and lasts for an average of 8 days. Some individuals exhibit watery diarrhea only. However, haemolytic uraemic syndrome is the principal cause of acute kidney failure in children, and most cases are caused by E. coli O157:H7.

E. coli O157:H7 infection has been associated with eating undercooked, contaminated minced beef. Because the organism lives in the intestines of healthy cattle, preventive measures on cattle farms and during meat processing are essential. Infection has also occurred after consumption of unpasteurized milk and apple cider, also sprouts, lettuce, and salami. Person-to-person transmission is important in families and child care settings, especially among toddlers who are not toilet-trained.

References:
Salmonellosis is one of the most common and widely distributed foodborne diseases. It constitutes a major public health burden and represents a significant cost in many countries. Millions of human cases are reported worldwide every year and the disease results in thousands of deaths. Salmonellosis is caused by the bacteria *Salmonella*. Today, there are over 2500 known types, or serotypes, of *Salmonella*. Salmonellae are found in the intestinal tracts of animals and humans, and some individuals are chronic carriers of the organism. Humans usually become infected by eating food contaminated with animal faeces, especially raw and undercooked foods of animal origin, such as beef, poultry, milk, and eggs. Food may also become contaminated through cross-contamination and poor hygiene of food handlers.

Salmonellosis results from consuming food contaminated by *Salmonella* spp. Infected persons develop diarrhoea, fever, and abdominal cramps between 12 and 72 hours after eating the contaminated food. The illness usually lasts 4–7 days, and most people recover without treatment. In vulnerable groups, such as the young infants and small children infection may spread beyond the intestine to the bloodstream and cause a more severe systemic disease. When Salmonella infections are systemic, they require antibiotic treatment. As the rates of multi-drug resistant strains increase, there are increasing difficulties in finding effective antimicrobials, especially for the treatment of infants and very small children.

References:
- CDC. Drug Resistance at CDC. Available at: www.cdc.gov/getsmart/ – accessed December 2009

Pictures: www.usda.gov/oc/photo/opclibra.htm
Shigellosis is an infectious disease caused by a group of bacteria called *Shigella*. Most who are infected with *Shigella* develop diarrhea, fever, and stomach cramps starting a day or two after they are exposed to the bacterium. The diarrhea is often bloody. Shigellosis usually resolves in 5 to 7 days. In some persons, especially young children and the elderly, the diarrhea can be so severe that the patient needs to be hospitalized. A severe infection with high fever may also be associated with seizures in children less than 2 years old. Some persons who are infected may have no symptoms at all, but may still pass the *Shigella* bacteria to others.

The *Shigella* bacteria pass from one infected person to the next. *Shigella* are present in the diarrheal stools of infected persons while they are sick and for a week or two afterwards. Most *Shigella* infections are the result of the bacterium passing from stools or soiled fingers of one person to the mouth of another person. This happens when basic hygiene and handwashing habits are inadequate. It is particularly likely to occur among toddlers who are not fully toilet-trained. Family members and playmates of such children are at high risk of becoming infected.

*Shigella* infections may be acquired from eating contaminated food. Contaminated food may look and smell normal. Food may become contaminated by infected food handlers who forget to wash their hands with soap after using the bathroom. Vegetables can become contaminated if they are harvested from a field with sewage in it. Flies can breed in infected feces and then contaminate food. *Shigella* infections can also be acquired by drinking or swimming in contaminated water. Water may become contaminated if sewage runs into it, or if someone with shigellosis swims in it.

There is no vaccine to prevent shigellosis. However, the spread of *Shigella* from an infected person to other persons can be stopped by frequent and careful handwashing with soap. Frequent handwashing is important among all age groups. Frequent, supervised handwashing of all children should be followed in day care centers and in homes with children who are not completely toilet-trained (including children in diapers). When possible, young children with a *Shigella* infection who are still in diapers should not be in contact with uninfected children.

People who have shigellosis should not prepare food or pour water for others until they have been shown to no longer be carrying the *Shigella* bacterium.

If a child in diapers has shigellosis, everyone who changes the child’s diapers should be sure the diapers are disposed of properly in a closed-lid garbage can, and should wash his or her hands carefully with soap and warm water immediately after changing the diapers. After use, the diaper changing area should be wiped down with a disinfectant such as household bleach, Lysol® or bactericidal wipes.

Basic food safety precautions and regular drinking water treatment prevents shigellosis. At swimming beaches, having enough bathrooms near the swimming area helps keep the water from becoming contaminated.
Enterobacter sakazakii is a gram-negative, non-spore-forming bacterium belonging to the Enterobacteriaceae family. On occasion, it has been associated with sporadic cases or small outbreaks of sepsis, meningitis, cerebritis and necrotizing enterocolitis.

Mortality rates from *E. sakazakii* infection have been reported to be as high as 50 percent or more, but this figure has declined to under 20 percent in recent years. Significant morbidity in the form of neurological deficits can result from infection, especially among those with bacterial meningitis and cerebritis. While the disease is usually responsive to antibiotic therapy, a number of authors have reported increasing antibiotic resistance to drugs commonly used for initial treatment of suspected *Enterobacter* infection. While the reservoir for *E. sakazakii* is unknown in many cases, a growing number of reports have established powdered infant formula as the source and vehicle of infection. In addition, the stomach of newborns, especially of premature babies, is less acidic than that of adults: a possible important factor contributing to the survival of an infection with *E. sakazakii* in infants. The frequency of intrinsic *E. sakazakii* contamination in powdered infant formula is of concern, even though intrinsic concentration levels of *E. sakazakii* appear to be typically very low. Intrinsic contamination of powdered formula with *E. sakazakii* or Salmonella can cause infection and illness in infants, including severe disease, and can lead to serious developmental sequelae and death. *E. sakazakii* has caused disease in all age groups. From the age distribution of reported cases, it is deduced that infants (children <1 year) are at particular risk. The infants at greatest risk from *E. sakazakii* infection are neonates (<28 days), particularly pre-term infants, low-birth-weight infants or immunocompromised infants. Infants of HIV-positive mothers are also at risk, because they may specifically require infant formula and they may be more susceptible to infection. The latter consideration, as well as low birth weight, may be of particular concern for some developing countries, where the proportion of such infants is higher than in developed countries.

There is a small but finite possibility that one or a small number of organisms in a serving could cause illness. This risk increases rapidly if the level of *E. sakazakii* is allowed to increase. Low numbers of *E. sakazakii* in powdered infant formula were also considered to be a significant risk factor, given the potential of even low numbers to multiply during preparation and holding prior to consumption of reconstituted formula.

Using current mix technology, it does not seem possible to produce commercially sterile powders or to completely eliminate the potential of contamination. Based on a preliminary risk assessment, the inclusion of a bactericidal step at the point of preparation and a decrease in holding and/or feeding time of the reconstituted formula were most effective in reducing risk. A combination of intervention measures had the greatest impact.

Some protozoa that cause foodborne diseases are *Toxoplasma gondii*, *Giardia lamblia*, and *Entamoeba histolytica*.

**Reference:**

Toxoplasmosis is a widespread parasitic disease that usually causes no symptoms in healthy human hosts. In pregnant women the organism *T. gondii* may infect the fetal brain, eyes and other tissues, even if the woman is asymptomatic. The infection can trigger miscarriage, stillbirth and preterm birth, or lead to mental retardation and blindness in the infant. The fetus is presumed to be at risk only if the mother has a primary, active infection during the pregnancy.

The birth prevalence of congenital toxoplasmosis throughout the world ranges from less than 1 to 10 per 10,000 live births. The age of the fetus may be a factor in maternal transmission, with the risk of fetal infection low during the first 8 weeks of pregnancy, and infection resulting mainly in spontaneous termination of the pregnancy. In one study, up to 90% of infected infants did not exhibit overt clinical signs of disease at birth. Of those with symptoms, many had severe neurological and development problems. In another study, visual impairment was observed in all children with congenital toxoplasmosis, while 74% had severe visual impairment. Of those with subclinical congenital infection at birth, up to 85% may develop chronic recurring eye disease and learning difficulties. The long-term impact carries high economic and societal costs.

Toxoplasmosis can be contracted by eating raw or undercooked meat or from exposure to the faeces of infected cats. Cats are an important host, with the parasite infecting the cells lining the cats' intestines. Farm animals may become infected when they ingest food or water contaminated by faeces from infected cats.

References:

Pictures:
On the left: Toxoplasma gondii cyst in brain tissue stained with hematoxylin and eosin (100×).
www.dpd.cdc.gov/dpdx/HTML/Image_Library.htm
On the right: www.dpd.cdc.gov/dpdx/HTML/Toxoplasmosis.htm
G. lamblia is spread through the faecal–oral route, either directly by person-to-person contact or through contaminated food or water. The parasite infects the small intestine and may cause diarrhoea, abdominal cramps and bloating, and result in malabsorption and weight loss.

Children are infected more frequently than adults, and the parasite is commonly found in day-care centres. The Centers for Disease Control and Prevention in the USA reports that giardiasis has been identified in 10–15% of children attending these centres who have not been toilet-trained. Approximately 20–25% of day-care staff and family contacts of infected children also become infected.

According to the US CDC (www.dpd.cdc.gov/dpdx/HTML/Giardiasis.htm):

- Giardia lives in the intestine of infected humans or animals. Millions of germs can be released in a bowel movement from an infected human or animal.
- Infection occurs after accidentally swallowing the parasite. Giardia may be found in soil, food, water, or surfaces that have been contaminated with the feces from infected humans or animals. Giardia is not spread by contact with blood. Giardia can be spread:
  - By eating or accidentally swallowing something that has come in contact with the stool of a person or animal infected with Giardia.
  - By swallowing recreational water contaminated with Giardia. Recreational water is water in swimming pools, hot tubs, jacuzzis, fountains, lakes, rivers, springs, ponds, or streams that can be contaminated with sewage or feces from humans or animals.
  - By eating uncooked food contaminated with Giardia. Thoroughly wash with uncontaminated water all vegetables and fruits that are eaten raw.
  - By accidentally swallowing Giardia picked up from surfaces (such as toys, bathroom fixtures, changing tables, diaper pails) contaminated with stool from an infected person.

Reference:

Entamoeba histolytica causes amebiasis. The most dramatic incident that occurred in the USA was the Chicago World's Fair outbreak in 1933 caused by contaminated drinking water; defective plumbing permitted sewage to contaminate the drinking water. There were 1,000 cases (with 58 deaths).

In recent times, food handlers are suspected of causing many scattered infections.


*Picture: www.dpd.cdc.gov/dpdx/HTML/Amebiasis.htm – accessed December 2009*
Some parasites that cause foodborne diseases include *Echinococcus, Anisakis simplex, Ascaris lumbricoides, and Trichinella species.*
Human echinococcosis (hydatidosis, or hydatid disease) is caused by the larval stages of cestodes (tapeworms) of the genus *Echinococcus*. *Echinococcus granulosus* causes cystic echinococcosis, the form most frequently encountered.

The adult *Echinococcus granulosus* (3 to 6 mm long) resides in the small bowel of the definitive hosts, dogs or other canids. Gravid proglottids release eggs that are passed in the feces. After ingestion by a suitable intermediate host (under natural conditions: sheep, goat, swine, cattle, horses, camel), the egg hatches in the small bowel and releases an oncosphere that penetrates the intestinal wall and migrates through the circulatory system into various organs, especially the liver and lungs. In these organs, the oncosphere develops into a cyst that enlarges gradually, producing protoscolices and daughter cysts that fill the cyst interior. The definitive host becomes infected by ingesting the cyst-containing organs of the infected intermediate host. After ingestion, the protoscolices evaginate, attach to the intestinal mucosa, and develop into adult stages in 32 to 80 days. *E. granulosus* occurs practically worldwide, and more frequently in rural, grazing areas where dogs ingest organs from infected animals.


Picture: CDC
Anisakiasis is most frequently diagnosed when the affected individual feels a tingling or tickling sensation in the throat and coughs up or manually extracts a nematode. In more severe cases there is acute abdominal pain, much like acute appendicitis accompanied by a nauseous feeling. Symptoms occur from as little as an hour to about 2 weeks after consumption of raw or undercooked seafood. One nematode is the usual number recovered from a patient. With their anterior ends, these larval nematodes from fish or shellfish usually burrow into the wall of the digestive tract to the level of the muscularis mucosae (occasionally they penetrate the intestinal wall completely and are found in the body cavity). They produce a substance that attracts eosinophils and other host white blood cells to the area. The infiltrating host cells form a granuloma in the tissues surrounding the penetrated worm. In the digestive tract lumen, the worm can detach and reattach to other sites on the wall. Anisakis rarely reach full maturity in humans and usually are eliminated spontaneously from the digestive tract lumen within 3 weeks of infection. Penetrated worms that die in the tissues are eventually removed by the host's phagocytic cells.


Approximately 1.22 billion people or about a quarter of the world population are infected with *Ascaris lumbricoides*, or roundworms. Infections with these parasites are more common where sanitation is poor, and human feces are used as fertilizer. Prevention of this infection centers around education, not using human feces as fertilizer, and cleanliness, especially among those who handle food.

They are found in the bathtub, toilet bowl, in diapers, or even on the pillow upon waking. Females can be well over a foot long; males are smaller. *Ascaris lumbricoides* infections in humans occur when an ingested infective egg releases a larval worm that penetrates the wall of the duodenum and enters the bloodstream. From here, it is carried to the liver and heart, and enters pulmonary circulation to break free in the alveoli, where it grows and molts. In 3 weeks, the larvae pass from the respiratory system to be coughed up, swallowed, and thus returned to the small intestine, where they mature to adult male and female worms. Fertilization can now occur and the female produces as many as 200,000 eggs per day for a year. These fertilized eggs become infectious after 2 weeks in soil; they can persist in soil for 10 years or more.

The eggs have a lipid layer, containing ascarocides and it makes them resistant to the effects of acids and alkalis as well as other unpleasant chemicals. This resilience helps to explain why this nematode is such a ubiquitous parasite.

The infection causes a wide range of symptoms that include intestinal manifestations (diarrhoea, abdominal pain), general malaise and weakness that may affect working and learning capacities, and impaired physical growth.

Reference:
Trichinellosis (trichinosis) is caused by nematodes (roundworms) of the genus *Trichinella*. Trichinellosis is acquired by ingesting meat containing cysts (encysted larvae) of *Trichinella*. After exposure to gastric acid and pepsin, the larvae are released from the cysts and invade the small bowel mucosa where they develop into adult worms (female 2.2 mm in length, males 1.2 mm; life span in the small bowel: 4 weeks). After 1 week, the females release larvae that migrate to the striated muscles where they encyst. *Trichinella pseudospiralis*, however, does not encyst. Encystment is completed in 4 to 5 weeks and the encysted larvae may remain viable for several years. Ingestion of the encysted larvae perpetuates the cycle. Rats and rodents are primarily responsible for maintaining the endemcity of this infection. Carnivorous/omnivorous animals, such as pigs or bears, feed on infected rodents or meat from other animals. Different animal hosts are implicated in the life cycle of the different species of *Trichinella*. Humans are accidentally infected when eating improperly processed meat of these carnivorous animals (or eating food contaminated with such meat). It is found mostly in parts of Europe and the United States.

Prions (pronounced pree ons) are self-replicating, or infectious proteins. Prion diseases, which are also known as transmissible spongiform encephalopathies (TSEs), are a family of rare progressive neurodegenerative disorders that affect both humans and animals. They are distinguished by long incubation periods, characteristic spongiform changes associated with neuronal loss, and a failure to induce inflammatory response.

Most well-known is variant Creutzfeld-Jakob disease caused by human ingestion of nerve material from infected cattle (first described in 1996). Once symptomatic, prion diseases are usually rapidly progressive and always fatal.

WHO has developed infection control guidelines for transmissible spongiform encephalopathies.

References:
•CDC. Prions. Available at www.cdc.gov/ncidod/dvrd/prions/- accessed December 2009
There are several other prion diseases that should be mentioned. Kuru was described in New Guinea among people who practiced cannibalism. Creutzfeldt-Jakob disease occurred among children who received human growth hormone treatment. Chronic wasting disease is a transmissible spongiform encephalopathy that occurs among elk and deer in Canada and the US. It is not known whether this can be transmitted to humans.

References:

BACKGROUND: Kuru provides the principal experience of epidemic human prion disease. Its incidence has steadily fallen after the abrupt cessation of its route of transmission (endocannibalism) in Papua New Guinea in the 1950s. The onset of variant Creutzfeldt-Jakob disease (vCJD), and the unknown prevalence of infection after the extensive dietary exposure to bovine spongiform encephalopathy (BSE) prions in the UK, has led to renewed interest in kuru. We investigated possible incubation periods, pathogenesis, and genetic susceptibility factors in kuru patients in Papua New Guinea. METHODS: We strengthened active kuru surveillance in 1996 with an expanded field team to investigate all suspected patients. Detailed histories of residence and exposure to mortuary feasts were obtained together with serial neurological examination, if possible. FINDINGS: We identified 11 patients with kuru from July, 1996, to June, 2004, all living in the South Fore. All patients were born before the cessation of cannibalism in the late 1950s. The minimum estimated incubation periods ranged from 34 to 41 years. However, likely incubation periods in men ranged from 39 to 56 years and could have been up to 7 years longer. PRNP analysis showed that most patients with kuru were heterozygous at polymorphic codon 129, a genotype associated with extended incubation periods and resistance to prion disease. INTERPRETATION: Incubation periods of infection with human prions can exceed 50 years. In human infection with BSE prions, species-barrier effects, which are characteristic of cross-species transmission, would be expected to further increase the mean and range of incubation periods, compared with recycling of prions within species. These data should inform attempts to model variant CJD epidemiology.


BACKGROUND: The emergence and continuing spread of Chronic Wasting Disease (CWD) in cervids has now reached 14 U.S. states, two Canadian provinces, and South Korea, producing a potential for transmission of CWD prions to humans and other animals globally. In 2005, CWD spread for the first time from the Midwest to more densely populated regions of the East Coast. As a result, a large cohort of individuals attending a wild game feast in upstate New York were exposed to a deer that was subsequently confirmed positive for CWD. METHODS: Eighty-one participants who ingested or otherwise were exposed to a deer with chronic wasting disease at a local...
New York State sportsman’s feast were recruited for this study. Participants were administered an exposure questionnaire and agreed to follow-up health evaluations longitudinally over the next six years. RESULTS: Our results indicate two types of risks for those who attended the feast, a Feast Risk and a General Risk. The larger the number of risk factors, the greater the risk to human health if CWD is transmissible to humans. Long-term surveillance of feast participants exposed to CWD is ongoing. CONCLUSION: The risk data from this study provide a relative scale for cumulative exposure to CWD-infected tissues and surfaces, and those in the upper tiers of cumulative risk may be most at risk if CWD is transmissible to humans.


Prion diseases are rare neurologic affections with a poor prognosis, occurring in both humans and animals. Creutzfeldt-Jakob disease (CJD) secondary to human extracted growth hormone treatment is the most frequent condition in pediatrics. In 1994, a new type of CJD (variant CJD) was described in young adults in the United Kingdom, only 10 years after the bovine spongiform encephalopathy epidemic, with recent works showing a direct relationship between the bovine epidemic and the human cases. An accumulation of a single protein called the prion protein (PrP) has been discovered in the brain in all of these cases, animal and human, leading to the hypothesis that a new infectious agent could proceed without any nuclear acid information; another hypothesis is that of a still unknown viral agent. The PRNP gene encoding for this PrP protein is well described: some mutations and a polymorphism in the 129th codon have been shown to be implicated in many cases of CJD. PrP is a ubiquitous protein, with yet unknown physiological function. There are still many questions to be answered: shall we expect new pediatric cases of variant CJD? Assuming that animal-human contamination is related to alimentation, are there other ways of contamination.
Toxins are produced by natural sources (usually bacteria or fungi), whereas toxicants are environmental contaminants that are not produced by natural sources. Many people mix the two up, but these terms have very specific, and different meanings.

Important toxins in food are botulinum toxin, a variety of mycotoxins, and microcystins. We will consider each of these individually.
Botulism is a rare, acute, descending flaccid paralysis caused by the neurotoxin produced by *C. botulinum*. Intoxication results from ingestion of food contaminated with the preformed toxin. Typical food vehicles include low-acid canned foods that have been improperly heat-processed, such as asparagus, green beans, beets and corn; more unusual sources have included chili peppers, chopped garlic, tomatoes stored in oil, and smoked vacuum-packed fish.

Infant botulism is a recognized variant first described in 1976. The illness in infants is caused by ingestion of *C. botulinum* spores, which subsequently germinate, multiply, and release toxin in the infant’s large intestine. A unique epidemiological feature of infant botulism is that all cases occur in children less than one year of age, with 95% of cases occurring in the first 6 months of life. Honey is a reservoir for *C. botulinum* and epidemiological studies have implicated honey consumption as a risk factor.

The clinical features include constipation, poor feeding, weakness, hypotonia, a striking loss of head control, dysphasia and, in severe cases, flaccid paralysis and respiratory failure. All forms of botulism can be fatal and are considered severe medical emergencies.

References:

Picture: USDA
Mycotoxins are poisonous substances produced by fungi, and have caused outbreaks of mycotoxicosis in humans and in livestock. Many outbreaks have been linked to eating mouldy food and feed because of food shortages or because of ignorance of the risks. Such practices continue in many parts of the world.

Reference:
Mycotoxins have also been linked to many chronic diseases, including cancer. Public health officials are beginning to recognise the importance of the problem. The Food and Agricultural Organization (FAO) of the United Nations has estimated that 25% of the world's food crops are contaminated by mycotoxins. A study in Asia and Africa estimated that 10 to 50% of crops are contaminated. In a Japanese study of *Fusarium* toxins in widely separated countries, only a few samples were not contaminated.

Slide courtesy of Dr. Gerald Moy (WHO)

<table>
<thead>
<tr>
<th>Chemical</th>
<th>Source</th>
<th>Associated food</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aflatoxins</td>
<td><em>Aspergillus flavus</em> and <em>A. parasiticus</em></td>
<td>corn, peanuts, tree nuts, milk</td>
</tr>
<tr>
<td>Trichotheccenes</td>
<td>Mainly <em>Fusarium</em></td>
<td>cereals and other foods</td>
</tr>
<tr>
<td>Ochratoxin A</td>
<td><em>Penicillium verrucosum</em> and <em>A. ochraceus</em></td>
<td>wheat, barley, corn</td>
</tr>
<tr>
<td>Ergot alkaloids</td>
<td><em>Claviceps purpurea</em></td>
<td>rye, barley, wheat</td>
</tr>
<tr>
<td>Fumonisins</td>
<td><em>Fusarium moniliforme</em></td>
<td>corn</td>
</tr>
<tr>
<td>Patulin</td>
<td><em>P. expansum</em></td>
<td>apples, pears</td>
</tr>
<tr>
<td>Zearalenone</td>
<td><em>Fusarium sps</em></td>
<td>cereals, oil, starch</td>
</tr>
</tbody>
</table>
The growth of moulds on agricultural commodities may result in the production of mycotoxins. For example, aflatoxins are produced by Aspergillus flavus growing on corn, peanuts and other nuts. Aflatoxins are potent mycotoxins that have caused much death and disease in Africa and Asia. These toxins are human carcinogens and considered one of the most dangerous contaminants of food and animal feed. Acute aflatoxicosis is produced when moderate to high levels of aflatoxins are consumed. Specific, acute episodes of disease ensue may include hemorrhage, acute liver damage, edema, alteration in digestion, absorption and/or metabolism of nutrients, and possibly death.

One of the most important accounts of aflatoxicosis in humans occurred in more than 150 villages in adjacent districts of two neighboring states in northwest India in the fall of 1974. According to one report of this outbreak, 397 persons were affected and 108 persons died. In this outbreak, contaminated corn was the major dietary constituent, and aflatoxin levels of 0.25 to 15 mg/kg were found. The daily aflatoxin B1 intake was estimated to have been at least 55 ug/kg body weight for an undetermined number of days. The patients experienced high fever, rapid progressive jaundice, edema of the limbs, pain, vomiting, and swollen livers. One investigator reported a peculiar and very notable feature of the outbreak: the appearance of signs of disease in one village population was preceded by a similar disease in domestic dogs, which was usually fatal. Histopathological examination of humans showed extensive bile duct proliferation and perportal fibrosis of the liver together with gastrointestinal hemorrhages. A 10-year follow-up of the Indian outbreak found the survivors fully recovered with no ill effects from the experience.

A second outbreak of aflatoxicosis was reported from Kenya in 1982. There were 20 hospital admissions with a 60% mortality; daily aflatoxin intake was estimated to be at least 38 ug/kg body weight for an undetermined number of days. In 2004 there were more outbreaks of acute aflatoxicosis in Kenya, involving 300 patients (more than 100 died). Chronic aflatoxicosis results from ingestion of low to moderate levels of aflatoxins. The effects are usually subclinical and difficult to recognize. Some of the common symptoms are impaired food conversion and slower rates of growth with or without the production of an overt aflatoxin syndrome. Cancer is also a long-term consequence. IARC has determined that naturally occurring mixtures of aflatoxins cause cancer. (Group 1: Carcinogenic to humans)

References:
• FDA Bad Bug Book Available at www.fda.gov/Food/FoodSafety/FoodborneIllness/FoodbornePathogensNaturalToxins/BadBugBook/ucm071020.htm – accessed December 2009

Picture: USDA
On top: Aspergillus flavus conidiophore.
Middle: Walnut infected with A. flavus.

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Picture: USDA
On top: Aspergillus flavus conidiophore.
Middle: Walnut infected with A. flavus.
Below: Atoxigenic A. flavus biocontrol grain growing on kernels of wheat.
Patulin is a mycotoxin produced by certain species of Penicillium, Aspergillus, and Byssochlamys moulds, and has been found in high levels in apple juice made from damaged and bruised apples. On the basis of adverse effects observed in animal studies, the Codex Alimentarius Commission has proposed a limit for patulin of 50 µg/kg in apple juice and apple juice ingredients in other beverages. In deriving this limit, apple juice consumption by children was considered because they consume higher amounts relative to their body weight than other age groups. Avoiding consumption of bruised apples can also reduce exposure to patulin.

References:
  The objective of the present study was to evaluate the patulin exposure of children consuming organic, handcrafted or conventional apple juice through a probabilistic approach and to evaluate the effectiveness of several risk management options aiming to reduce the risk for children due to patulin exposure. However, a large part of the data on patulin contamination of apple juice fell under the limit of detection (LOD). Different methods were tested to deal with these so-called left censored data and a uniform distribution with uncertain bounds was selected to handle this censorship. Variability and uncertainty assessment of patulin exposure showed that 0.9% [90% confidence interval (CI): 0.3-1.8%] of the children consuming only organic apple juice exceed the tolerable daily intake (TDI). For consumers of conventional and handcrafted apple juice this was respectively 0.1% [90% CI: 0.0-0.3%] and 0% [90% CI: 0-0.2%]. Reduction of the patulin contamination in apple juice to concentrations below 25 microg/kg reduced the percentage of the children exceeding the TDI to 0% [90% CI: 0-0.2%] for organic apple juice. Reduction of the apple juice consumption was less effective than a reduction of the patulin concentration in apple juice and is only useful when the patulin concentration of apple juice is below 25 microg/kg.

The trichothecenes are a family of toxins produced by many species of *Fusarium*, *Stachybotrys*, and *Trichoderma* fungi. IARC has evaluated them and made a determination that deoxynivalenol, nivalenol, and T-2 toxin are not classifiable with respect to whether or not they cause cancer. (IARC Group 3: Not classifiable.)

**References:**

  During June to September, 1987, there were reports that a considerable segment of the population of Kashmir Valley, India, were affected by a gastrointestinal disorder. Epidemiological investigations and laboratory based studies indicated that the outbreak was associated with the consumption of bread made from mould-damaged wheat. The disease was not age or sex specific. Evidence of mould damage of wheat consisted of the presence of moulds (such as *Fusarium* sp, *Aspergillus* sp), and varying quantities of trichothecene mycotoxins (such as deoxynivalenol, nivalenol, acetyldeoxynivalenol, T-2 toxin) in samples tested. The symptoms were reproduced in dogs fed extracts of contaminated samples. The finding that trichothecene mycotoxins, especially deoxynivalenol trichothecene, cause symptoms in man emphasizes the need for a reappraisal of its safety limits in food.


This study reports estimates on dietary exposure from the first French Total Diet Study (FTDS) and compares these estimates with both existing tolerable daily intakes for these toxins and the intakes calculated during previous French studies. To estimate the dietary exposure of the French population to the principal mycotoxins in the French diet (as consumed), 456 composite samples were prepared from 2280 individual samples and analysed for aflatoxins, ochratoxin A, trichothecenes, zearalenone, fumonisins and patulin. Average and high percentile intakes were calculated taking account of different eating patterns for adults, children and vegetarians. The results showed that contaminant levels observed in the foods examined "as consumed" complied fully with...
current European legislation. However, particular attention needs to be paid to the exposure of specific population groups, such as children and vegans/macrobiotics, who could be exposed to certain mycotoxins in quantities that exceed the tolerable or weekly daily intake levels. This observation is particularly relevant with respect to ochratoxin A, deoxynivalenol and zearalenone. For these mycotoxins, cereals and cereal products were the main contributors to high exposure.

Picture: WHO
IARC found that *Fusarium moniliforme* culture material and naturally-contaminated corn were possible human carcinogens. The toxin is neither mutagenic nor genotoxic.

**References:**

**Picture:** WHO
Mycotoxins differ in their chemical and physical properties but most can be considered relatively stable to heat and other processes normally applied in the production and preparation of food. A number of countries have established limits for mycotoxins in particularly susceptible foods.

Reference:
The presence of blue–green algae (BGA) toxins in surface waters used for drinking water sources and recreation is receiving increasing attention around the world as a public health concern. However, potential risks from exposure to these toxins in contaminated health food products that contain BGA have been largely ignored. BGA products are commonly consumed in the United States, Canada, and Europe for their putative beneficial effects, including increased energy and elevated mood. Many of these products contain *Aphanizomenon flos-aquae*, a BGA that is harvested from Upper Klamath Lake (UKL) in southern Oregon, where the growth of a toxic BGA, *Microcystis aeruginosa*, is a regular occurrence. *M. aeruginosa* produces compounds called microcystins, which are potent hepatotoxins and probable tumor promoters. Because *M. aeruginosa* coexists with *A. flos-aquae*, it can be collected inadvertently during the harvesting process, resulting in microcystin contamination of BGA products. In fall 1996, the Oregon Health Division learned that UKL was experiencing an extensive *M. aeruginosa* bloom, and an advisory was issued recommending against water contact. The advisory prompted calls from consumers of BGA products, who expressed concern about possible contamination of these products with microcystins. In response, the Oregon Health Division and the Oregon Department of Agriculture established a regulatory limit of 1 μg/g for microcystins in BGA-containing products and tested BGA products for the presence of microcystins. Microcystins were detected in 85 of 87 samples tested, with 63 samples (72%) containing concentrations > 1 μg/g. HPLC and ELISA tentatively identified microcystin-LR, the most toxic microcystin variant, as the predominant congener.

**References:**


Foodborne diseases are likely to increase with global climate change. This is partly because of changes in eating behaviour including more outdoor food preparation and dining, and partly because many foodborne pathogens grow faster in warmer weather. There will be more children with diarrhoea and likely more hospitalizations for dehydration. In one 6-year study from Peru, researchers found an 8% increase in hospitalizations for diarrhoea and dehydration for every degree centigrade above the normal average temperature. This analysis controlled for seasonal variations and long-term trends, thus imparting high confidence to the observed relationship of diarrhoeal disease with temperature.

This chart shows a clear correlation between peak temperatures and peaks in cases of *Campylobacter*, *E. coli*, and *Salmonella* infections in Alberta, Canada. Hot weather yields more illness.

**References:**


A time series analysis in Fiji assessed the relation between monthly reported incidence of diarrhoea and variations in temperature and rainfall, allowing for the effects of seasonal variation and long-term trends. The reported incidence increased by approximately 3% for each degree increase in temperature, by 2% per unit increase in rainfall above $5 \times 10^{-5}$ kg/m$^2$ per minute (average rainfall conditions), and by 8% per unit decrease in rainfall below this level.

Future changes in mean climatic conditions and in the occurrence of extreme weather events are likely to significantly affect the incidence of diarrhoeal disease in children. As well as meteorological influences on microbial exposures, child diarrhoeal disease may also increase because drinking water becomes contaminated by toxins from warming-induced algal blooms.

Reference:


ABSTRACT: Freshwater resources are a high-priority issue in the Pacific region. Water shortage is a serious problem in many small island states, and many depend heavily on rainwater as the source of their water. Lack of safe water supplies is an important factor in diarrheal illness. There have been no previous studies looking specifically at the relationship between climate variability and diarrhea in the Pacific region. We carried out two related studies to explore the potential relationship between climate variability and the incidence of diarrhea in the Pacific Islands. In the first study, we examined the average annual rates of diarrhea in adults, as well as temperature and water availability from 1986 to 1994 for 18 Pacific Island countries. There was a positive association between annual average temperature and the rate of diarrhea reports, and a negative association between water availability and diarrhea rates. In the second study, we examined diarrhea notifications in Fiji in relation to estimates of temperature and rainfall, using Poisson regression analysis of monthly data for 1978-1998. There were positive associations between diarrhea reports and temperature and between diarrhea reports and extremes of rainfall. These results are consistent with previous research and suggest that global climate change is likely to exacerbate diarrheal illness in many Pacific Island countries.

Global climate change is likely to lead to warmer temperatures and extreme weather events. These encourage the growth of mycotoxin-producing fungi, including Aspergillus, Claviceps, Stachybotrys, and Fusarium spp. Mycotoxins are implicated in the pathogenesis of cancers, ergotism, and birth defects.

Reference:


Human activity has contributed to climate change. The relationship between climate and child health has not been well investigated. This review discusses the role of climate change on child health and suggests 3 ways in which this relationship may manifest. First, environmental changes associated with anthropogenic greenhouse gases can lead to respiratory diseases, sunburn, melanoma, and immunosuppression. Second, climate change may directly cause heat stroke, drowning, gastrointestinal diseases, and psychosocial maldevelopment. Third, ecologic alterations triggered by climate change can increase rates of malnutrition, allergies and exposure to mycotoxins, vector-borne diseases (malaria, dengue, encephalitides, Lyme disease), and emerging infectious diseases. Further climate change is likely, given global industrial and political realities. Proactive and preventative physician action, research focused on the differential effects of climate change on subpopulations including children, and policy advocacy on the individual and federal levels could contain climate change and inform appropriate prevention and response.
Some chemicals that can cause foodborne diseases include pesticides, persistent organic pollutants (POPs), mercury, lead, and some food additives.
Pesticides perform an important role in maximizing agricultural production and protecting the food supply. But because of their inherent toxicity and widespread use, pesticides also pose a threat to public health, particularly to infants and children. High doses of pesticides cause acute poisoning. Epidemiological studies and laboratory studies in animals contribute to a growing body of evidence linking pesticide exposure to adverse health effects including cancer, birth defects, reproductive harm, neurological and developmental toxicity, immunotoxicity and disruption of the endocrine system. A major concern for the young is that, during the first six years of life, the child’s central nervous system is still developing and is likely to be vulnerable to neurotoxic pesticides. Most major classes of pesticides, including the organochlorines, organophosphorus compounds, carbamates, chlorophenoxy herbicides, and pyrethroids, have been shown to adversely affect the developing nervous system of laboratory animals, altering neurological function and causing subtle neurobehavioural impairments. Many of these pesticides share a common mechanism of toxicity, but their cumulative impact on children’s health has not yet been fully assessed.

Picture: Ceppi, Corra. Argentina, young boys and rural work with pesticides. Used with permission
Persistent organic pollutants (POPs) are a group of toxic chemical substances that persist in the environment, bioaccumulate along the food chain, and are a risk to human health. Twelve substances were initially classified as POPs under the Stockholm Convention: aldrin, chlordane, dichlorodiphenyl trichloroethane (DDT), dieldrin, endrin, heptachlor, mirex, toxaphene, polychlorinated biphenyls (PCBs), hexachlorobenzene, dioxins and dibenzofurans. Most of these, with the exception of DDT used for malaria control, have been, or are in the process of being, phased out. Since 2009, the list has also extended to include new substances.

POPs resist biodegradation and are insoluble in water, but are readily stored in fatty tissue where concentrations can reach 70,000 times the background level. Long-lived species of fish, birds and mammals, including humans, have the greatest concentrations. These pollutants may accumulate in fatty tissues in the human body for many years, and may be passed to infants in breast milk.

The potential health effects of POPs include cancer, allergies, hypersensitivity and disorders of the nervous and immune systems. Of particular concern are dioxins (including dibenzofurans and dioxin-like PCBs) that may function as endocrine disrupters. Low-level exposure to such substances is particularly critical for the fetus and infants, because of their very low levels of circulating hormones. Dioxins can pass through the placenta directly to the fetus, and may cause developmental problems. Breastfeeding infants can receive up to 14% of their lifetime exposure to dioxins through breast milk. Because reproductive and developmental processes are extremely sensitive to endocrine-disruptive compounds, there is an urgent need for better risk characterization and improved evaluation procedures. In any case, it may be prudent to reduce the use and emissions of these substances and to establish limits for their presence in food and animal feed.

An assessment of the current knowledge on endocrine disrupters has been prepared by WHO through the International Programme on Chemical Safety. At the country level the evidence proves that restrictions and bans work. This slide shows long-term trends in Sweden of decreasing breast milk contamination with POPs like DDT and dieldrin.

**References:**

**Pictures:** Solomon, Chemical contaminants in breast milk: time trends and regional variability. *EHP* (2002) 110 (6), A339. Reproduced with permission from EHP.
• POPs have an anthropogenic origin: industrial processes, waste (e.g. medical), traffic and agriculture. A few may be of natural origin, e.g. from volcanic eruptions.
• POPs are released into air, water and land – from where they deposit into water, sediment, and enter the food-chain
• POPs are globally distributed through the air and ocean currents – they travel long distances and enter into atmospheric processes, air–water exchange and cycles involving rain, snow and dry particles. These processes lead to the exposure of even remote populations of humans and animals that depend on aquatic foods. Humans and animals are exposed mainly via ingestion of contaminated aquatic foodstuffs.
• POPs travel long distances and are found in places far away from industrial sites or from agricultural areas, such as the Arctic circle.

Picture: UNEP

References:
This graph shows the temporal trend of PCDD/F in human milk. The dark green bars are from 1988, the light green bars are from 1993, and the yellow bars are from 2002. You can see that levels of PCDD/F in human milk are decreasing over time in many different countries.

*Slide kindly provided by Dr. G. Moy (WHO)*
Despite the fact that POPs can be found in breast milk, there are many advantages of breastfeeding.

<<READ SLIDE>>
Mercury occurs naturally in soils and rocks but is also used in a number of industrial applications. Organic mercury, principally in the form of methylmercury, is the most hazardous form.

Food is the main source of exposure to methylmercury and, for the fetus, the main source of exposure is the maternal diet. The highest levels of mercury in food are typically found in fish, particularly the long-lived, large, predatory fish at the top of the food chain, e.g. shark, swordfish, and tuna.

For the vast majority of consumers, the level of mercury in fish does not pose any significant health risk. However, the fetus and young children are more vulnerable to the harmful effects of mercury than adults. Mercury is toxic to the developing foetal brain, and exposure in the womb may lead to neurobehavioural effects such as deficits in motor skills, attention, language, visual-spatial skills and memory. The Codex Alimentarius Commission has established guideline levels for total mercury in predatory and non-predatory fish. In some countries, pregnant women are advised to limit their consumption of certain fish.

<<NOTE TO USER: Please refer to module on Mercury in the WHO Training Package for the Health Sector>>
It is important to recognize that large predator fish have the highest levels of mercury and the lowest levels of omega 3 fatty acids, while small fish have the lowest levels of mercury and the highest levels of omega 3 fatty acids.

Reference:

Picture: WHO
Lead occurs naturally in the environment and has many industrial uses. Small amounts of lead can be harmful, especially to the fetus, infant and young child. During pregnancy, especially in the last trimester, lead can cross the placenta. Cognitive and growth defects may occur in infants whose mothers are exposed to lead during pregnancy. Lead exposure is also serious for young children because they absorb it more easily than adults and are more susceptible to its harmful effects. Even low-level exposure may reduce intelligence, result in learning disabilities and behavioural abnormalities, and cause kidney damage.

Airborne lead from automobile exhaust may contaminate crops or soil; lead may also be introduced into water by certain household water systems. Lead can enter food, especially acidic food such as fruit juice, from lead-based glazes and lead-soldered cans. It may also be an intentional (or non-intentional) contaminant in spices (e.g. paprika) and cosmetics (e.g. kohl). Infants may also ingest lead in breast milk.

There is no threshold level believed to be safe for infants and young children. However, the Joint FAO/WHO Expert Committee on Food Additives (JECFA) has established a provisional tolerable weekly intake (PTWI) for lead of 0.025 mg/kg of body weight.

Reference:

<<NOTE TO USER: Please refer to module on Lead in the WHO Training Package for Health Care Providers.>>
Public health concerns about the use of food additives, such as preservatives, artificial colouring agents, flavour enhancers, sweeteners, and antimicrobials, are generally unfounded. Most industrialized countries have registration and approval processes which are designed to ensure that only substances that have met exacting safety assessments are used. JECFA provides reference intakes for a range of direct and indirect food additives. An acceptable daily intake (ADI) may be established for a chemical and its toxicologically significant degradation and metabolic products if data demonstrate that exposure to the chemical under its proposed conditions of use would pose no appreciable risk to the consumer over a lifetime. JECFA has, however, stated that ADIs should not be considered applicable to neonates and infants up to the age of 12 weeks. In addition, there is some evidence to suggest that certain food additives may produce specific effects in children, such as attention and hyperactivity disorders.

The consumption of supplementary vitamins and minerals is indicated in certain situations, but excessive use may pose health problems. Commercial fortified products include vitamin D fortified milk, iodized salt, and iron-supplemented cereals. In addition, there is widespread promotion of the use by pregnant women of folic acid supplements to prevent spina bifida, vitamin K to prevent haemorrhagic disease of the newborn, and vitamin A to reduce the risk of xerophthalmia in infants. However, there are also dangers associated with excessive intake of vitamins and minerals. For example, excess vitamin A can result in bone disease and increased intracranial pressure, while excess vitamin D can cause kidney disease. Such excesses are unlikely to be a result of dietary intake, but rather of excessive use of supplements. Consequently, it is best to seek medical advice before taking such supplements.

Food additives that have gone through regulatory testing and have been assessed (e.g. by JEFCA) are considered safe. Food additives that have gone through regulatory testing and have been assessed (e.g. by JEFCA: Joint FAO/WHO Expert Committee on Food Additives) are considered safe.

Reference:

Picture: WHO
There was a food contamination event in 2008 in China, involving infant formula that was contaminated with melamine. Over 6240 cases of kidney stones in infants (with three deaths) were reported from across China as of 17 September, 2008. Kidney stones in infants are very rare. The Ministry of Health of China confirmed that these cases were related to melamine-contaminated powdered infant formula consumed by the infants. While the exact onset date of illness resulting from contamination is unknown, a manufacturer received a complaint of illness in March 2008. Following inspections conducted by China’s national inspection agency, at least 22 dairy manufacturers across the country were found to have melamine in some of their products (levels varied between 0.09mg/kg and 2.560 mg/kg). Two companies exported their products to Bangladesh, Burundi, Myanmar, Gabon and Yemen. While contamination in those exported products remains unconfirmed, a recall was ordered from China.

The TDI (tolerable daily intake) for melamine has been established at 0.2 mg/kg body weight. Based on this, a 5 kg infant can have a tolerable amount of 1 mg melamine per day.

References:

BACKGROUND: A recent epidemic of melamine contamination of baby formula in China has been associated with the development of urinary tract stones, though the clinical manifestations and predisposing factors are incompletely delineated. METHODS: We administered a questionnaire to the parents of children 36 months of age or younger who were being screened for a history of exposure to melamine and symptoms of, and possible predisposing factors for, urinary tract stones. In addition, we performed urinalysis, renal-function and liver-function
tests, urinary tests for biochemical markers and the calcium:creatinine ratio, and ultrasonography. Powdered-milk infant formulas were classified as having a high melamine content (>500 ppm), a moderate melamine content (<150 ppm), or no melamine (0 ppm); no formulas contained between 150 and 500 ppm of melamine. RESULTS: Contaminated formula was ingested by 421 of 589 children. Fifty had urinary stones, including 8 who had not received melamine-contaminated formula; 112 were suspected to have stones; and 427 had no stones. Among children with stones, 5.9% had hematuria and 2.9% had leukocyturia, percentages that did not differ significantly from those among children who were suspected to have stones or those who did not have stones. Serum creatinine, urea nitrogen, and alanine aminotransferase levels were normal in the 22 children with stones who were tested. Four of the 41 children (9.8%) who had stones and in whom urinary markers of glomerular function were measured had evidence of abnormalities; none had tubular dysfunction. Children exposed to high-melamine formula were 7.0 times as likely to have stones as those exposed to no-melamine formula. Preterm infants were 4.5 times as likely to have stones as term infants. CONCLUSIONS: Prematurity and exposure to melamine-contaminated formula were associated with urinary stones. Affected children lacked typical signs and symptoms of urolithiasis.

Children and Food Safety

FOODBORNE HAZARDS: DEVELOPING FOETUS

Pictures: WHO
The developing fetus is at risk from infectious agents and toxic chemicals that may cross the placenta. Obviously, the exposure of the fetus is a result of exposure of the woman during pregnancy and, in some cases, before pregnancy. Because of the potential adverse health outcome for the developing fetus, women should be informed about these foodborne hazards.

Toxoplasmosis

There is currently insufficient evidence to confirm that treating mothers who seroconvert during pregnancy can prevent fetal infection and improve infant outcomes.
The increased use of refrigeration to prolong the shelf life of food has contributed to the emergence of *L. monocytogenes* as a food hazard.

For pregnant women the following advice should be given:
- Do not eat refrigerated pates, meat spreads, or cold meats
- Do not drink unpasteurized milk or eat foods that contain unpasteurized milk.
- Do not eat soft unpasteurized cheese or blue-vein cheese.
- Do not eat prepared or stored salads.
- Do not eat refrigerated smoked seafood such as salmon, trout, tuna, or mackerel.
- Do not eat raw fish such as sashimi, sushi, ceviche, roe, mussels or oysters.
- Do not eat refrigerated foods that are past their expiry dates.
Because methylmercury is eliminated slowly from the body, a mother can decrease the potential exposure to a foetus by eliminating all high mercury containing fish for 6-12 months prior to pregnancy. Lead, however, is not eliminated from the body, and will enter the circulation from bone during pregnancy unless the mother is well nourished particularly with calcium-containing foods.

<table>
<thead>
<tr>
<th>Disease/Agent</th>
<th>Hazard</th>
<th>Risk Reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heavy metals</td>
<td>Heavy metals may cross the placenta resulting in exposure of the developing foetus. These substances can be neurotoxic, result in reduced intelligence, and lead to behavioural problems.</td>
<td>Methylmercury: Avoid consuming large amounts of fish that bioaccumulate methylmercury, such as large predatory fish (e.g. tuna, swordfish, etc). Lead: Avoid ceramic dishes and canned food with lead-soldered seams. Wash vegetables and fruit thoroughly Avoid food produced or prepared near busy roads.</td>
</tr>
</tbody>
</table>
POPs build up in the body over a lifetime, therefore a mother may not be able to have significant impact on body burden and foetal exposure unless she has been careful to avoid foods high in POPs since childhood.

### Children and Food Safety

#### FOODBORNE HAZARDS: DEVELOPING FOETUS

<table>
<thead>
<tr>
<th>Disease/Agent</th>
<th>Hazard</th>
<th>Risk Reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>POPs including dioxins and PCBs</td>
<td>POPs may cross the placenta resulting in exposure of the developing foetus. POPs may cause behavioural problems, hormone disturbances, and cancer.</td>
<td>Avoid foods (esp. meat and dairy products) that may contain high levels of POPs (persistent organic pollutants). <strong>NOTE</strong>: It is important to reduce the use and emissions of POPs and to establish limits for food and animal feed.</td>
</tr>
</tbody>
</table>
Drinking alcohol during pregnancy can cause birth defects and developmental disabilities. Children exposed to alcohol in the womb can suffer an array of disorders, from subtle changes in intelligence to profound mental retardation. They may also suffer growth retardation and be born with birth defects.

One of the most severe outcomes is **foetal alcohol syndrome** (FAS), which includes three abnormalities – disorder of the brain, growth retardation, and facial malformation, and foetal alcohol spectrum disorders (FASD).

<<READ SLIDE>>
Breast milk is the most nutritious and safest food for the newborn infant. Exclusive breastfeeding minimizes exposure of the infant to foodborne and waterborne pathogenic microorganisms, and confers protection to the infant through the anti-infective properties of breast milk. However breastfed infants can be at risk from a range of chemicals that may be present in breast milk. These may come from the maternal diet during nursing, but may also come from the release of substances that had accumulated in the mother's adipose tissue. Certain infectious agents may also be transmitted through breast milk.

Bottle-fed infants may be exposed to a range of food- and waterborne pathogens. Bacterial contamination of bottles is an important source of diarrhoea in infants. This is particularly a problem in developing countries and in other situations where environmental sanitation is poor. Breast-milk substitutes, such as powdered infant formula, may contain viable pathogenic microorganisms. Infections in infants fed with contaminated formula products containing *Salmonella* spp. and other bacteria from the family *Enterobacteriaceae* have been reported. In some countries, teats contaminated with N-nitrosamines can still be found.

References:


Picture: WHO
Children and Food Safety

PREVENTING BACTERIAL FOODBORNE DISEASES IN INFANTS

❖ Breast milk is the safest food for infants.
  • Sterile in healthy mother
  • Good personal hygiene

❖ If bottle feeding
  • Select good quality infant formula.
  • Use safe or boiled water when preparing formula.
  • If using powdered infant formula (non-sterile) bring reconstituted mix to 70°C and then cool.
  • Do not store prepared formula.
  • Wash and boil bottles and teats after every feeding. If possible, use a cup instead.
  • Wash hands after changing the baby, using the toilet, handling raw food or touching animals.
  • Follow safe food handling practices.
Exposure of the infant to substances such as lead and methylmercury can be neurotoxic, result in reduced intelligence, and lead to behavioural problems.

**Lead**
Avoid ceramic dishes and canned food with lead-soldered seams. Wash vegetables and fruit thoroughly. Avoid food produced or prepared near busy roads.

**Methylmercury**
Avoid consuming large amounts of fish that bioaccumulate methylmercury, such as large predatory fish.

**POPs including dioxins and PCBs**
Exposure of the infant can lead to behavioural problems, hormone disturbances, and cancer. Human breast milk may contain lipophilic POPs. Avoid excessive weight loss during breastfeeding. **NOTE: It is important to reduce the use and emissions of POPs and to establish limits for food and animal feed.**

References:
This is a review of some of the potential hazards for formula-fed infants. These include contamination of formula with bacteria from the water used to prepare the formula, contamination of powdered infant formula with melamine, Enterobacter sakazakii, or Salmonella, and preparing infant formula using water with high nitrate concentrations.

Methaemoglobinaemia - Ingestion of nitrate and nitrite by infants results in the formation of methaemoglobin, which reduces the oxygen-carrying capacity of blood. Ensure well water and water used to prepare breast milk substitutes is low in nitrate.

More rare hazards have occurred when soy milk formula was marketed without salt, resulting in some infant deaths (1978).

Reference:
When infants reach the age of about 6 months, they should normally be given complementary foods to meet their evolving nutrient requirements. With the introduction of such foods, infants may be exposed to a range of contaminants. These include pathogenic microorganisms and their toxins, and various chemical contaminants of foodstuffs, e.g. lead, mercury and pesticides. Diarrhoea is a leading cause of death in children under the age of five. In developing countries, diarrhoeal disease may be responsible for over 40% of all deaths in children. Contaminated complementary foods account for a substantial proportion of diarrhoeal illness among infants and young children. Such foods may also expose infants to toxic chemical substances.

References:
The following set of slides are part of the WHO "train the trainers" materials "Five keys to safer food" – developed by the Department of Food Safety, Zoonoses and Foodborne Diseases (FOS), that has kindly lent them for inclusion in this module. For more information on these materials, please visit the website www.who.int/foodsafety/consumer/5keys/en/index.html
This slide presents Key 1 from the Five Keys to Safer Food poster. The simple message, and the behaviour that must be practiced for Key 1 is “Keep Clean”. The "core information" describes how to keep hands and the food preparation areas clean. The “why” provides a simple explanation of why the behaviour is important. Several studies have shown that adults are more likely to adopt a behaviour when they understand the reason why the practice is important.

Adaptation Tip: The Five Keys to Safer Food manual contains recommendations for simplifying the language for the information contained in this slide.
Many people believe that food must look spoiled or dirty to be harmful. However, since microorganisms and chemicals are too small to see; even when something looks clean, harmful microorganisms and chemicals may still be present.

Cleaning removes but does not kill microorganisms. Therefore the water and cloths used for cleaning can become contaminated with microorganisms.

The importance of hand washing should be stressed. When cleaning hands it is best to use soap and warm running water.

For hand washing in particular it is important to not wash hands in a bowl of water. The microorganism that cause disease can survive in a bowl of water and even grow.

Washing or peeling food can remove chemicals from the outside of the food. However, in some cases the chemicals are actually in the food (e.g., mercury in fish). In this case, washing the outside of the food will not be sufficient to remove chemicals from food.

Adaptation Tip: In preparing the train the trainer session, the moderator may want to add additional information tailored to the local in-country conditions.
This slide presents Key 2 from in the Five Keys to Safer Food poster. The simple message for Key 2 is “Separate raw and cooked” foods. The “core information” describes how to properly separate raw and cook food. The “why” provides a simple explanation of why the behaviour is important. Several studies have shown that adults are more likely to adopt a behaviour when they understand the reason why the practice is important.

Adaptation Tip: The Five Keys to Safer Food manual contains recommendations for simplifying the concepts presented in this slide.
Cross-contamination is a term used to describe the transfer of microorganisms from raw to cooked food.

Cross-contamination can occur at any point in food handling from slaughter until consumption. Separation of raw and cooked foods must occur throughout all phases of food preparation including growing of crops, slaughter of animals, selling, purchasing, preparation and storage slaughter to prevent dangerous microorganisms on raw foods from transferring to cooked food.

It is important to remember that when a plate has been used for raw food it should not be used again for cooked food until it is washed with soap and water.

To prevent the transfer of disease-causing microorganisms from raw foods to cook foods during storage, raw foods should be stored below cooked foods. The juices from the raw food can drip onto and contaminate the cooked food.

Adaptation Tip: In preparing the train the trainer session, the moderator may want to add additional information tailored to the local in-country conditions. For example, if animals often roam in field where fresh vegetables are grown, the trainer should point out that this causes cross-contamination. Alternatively, if cooking of meat on a Barbeque is common, the moderator should remind participants that placing cook meat on the plate that held raw meat is a common source of cross-contamination.
This slide presents Key 3 from the Five Keys to Safer Food poster. The simple message for Key 3 is “Cook Thoroughly”. The “core information” describes how to properly cook food. The “why” provides a simple explanation of why the behaviour is important. Several studies have shown that adults are more likely to adopt a behaviour when they understand the reason why the practice is important.

Adaptation Tip: In countries that use Fahrenheit temperatures for food preparation, the moderator should use 158 °F, the exact conversion of 70 °C to Fahrenheit. Trainers may prefer to use an “rounded” figure of 160 °F when teaching the material to women.
Since bacteria are found on the outer surface of meat, the centre of an intact piece of meat is usually sterile and safe from bacteria. However, when meat is minced or ground, the bacteria on the outside are mixed into the meat and thus are present throughout the meat. It is important to cook these foods until the centre reaches a temperature of 70°C.

Cooking foods to a temperature above 70°C kills microorganisms on foods within 30 seconds.

When food must be prepared at lower temperatures, a longer cooking time is needed because the microorganisms are being killed at a slower rate and more time is needed to ensure they are killed.

When reheating already cooked foods, they should be reheated until piping hot (70°C) throughout the entire food. The middle of the food should not still be cool.

Adaptation Tip: In some parts of the world, minced meat is called ground meat. Other adaptations in the terminology may be helpful. It should be noted that some national authorities have develop different cooking temperatures for different meats. WHO has found that 70°C is protective. In countries that use Fahrenheit, the moderator should use 158°F, the exact conversion of 70°C to Fahrenheit.

In countries that use a microwave to reheat food, there is an increased likelihood that the reheating will not result in 70°C throughout. The importance of proper reheating should be stressed as this is a common source of contamination. Dishes that are thoroughly cooked are sterile but often become contaminated during serving. Women may not see the point of reheating foods only to have to wait for them to cool before eating. However, if the reheating is not complete, microorganisms can grow in the reheated foods.
This slide presents Key 4 from the Five Keys to Safer Food poster. The simple message for Key 4 is “Keep food at safe temperatures”. The "core information" describes how to properly keep food at safe temperatures. The “why” provides a simple explanation of why the behaviour is important. Several studies have shown that adults are more likely to adopt a behaviour when they understand the reason why the practise is important.

Adaptation Tip: The Five Keys to Safer Food manual contains recommendations on how to simplify and explain this concept.
Between a temperature range of 5°C-60°C, microorganisms grow very quickly. While chilling and freezing does not kill microorganisms but limits growth. Buying and preparing smaller portions of food can decrease the need for storage.

Adaptation Tip: There are options besides refrigerators for storing foods below 5°C. These include ice boxes/coolers, cold water, pantries built over streams, and digging a hole. If storing foods below 5°C is not possible, it might be reasonable to obtain fresh foods and use them quickly.

In countries that use Fahrenheit, the moderator should use 41°F, the exact conversion of 5°C to Fahrenheit and 140°F, the exact conversion of 60°C to Fahrenheit.
This slide presents Key 5 from the Five Keys to Safer Food poster. The simple message for Key 5 is “Use Safe Water and Raw Materials”. The “core information” describes how to select safe water and raw materials. The “why” provides a simple explanation of why the behaviour is important. Several studies have shown that adults are more likely to adopt a behaviour when they understand the reason why the practice is important.
Rainwater that is collected in a tank is safe as long as the tank is clean and has not been used for anything else. Water from canals and rivers is not safe because it contains dangerous microorganisms. However, this unsafe water can be treated to inactivate microorganisms by bringing the water to a rolling boil, adding 3-5 drops of chlorine per litre, and filtration.

Fresh fruits and vegetables should be washed with clean, safe water. Peeling fresh fruits and vegetables can remove chemicals and microorganisms from the outside surface of the fruit or vegetable. In some cases, chemicals and microorganisms can enter the fruit or vegetable. These products must be grown under conditions that prevent contamination.
In this summary slide, you see the complexity of the issues related to children's environmental health. Hazards are introduced into environmental media with variable efficiency in different settings. A child's activities brings him into contact with these hazards. Depending upon the individual susceptibility of the child based upon age, general health and social supports, the exposure may cause harm from subtle changes in function to death. Children's environmental health is the field which synthesizes these complexities and attempts to make fundamental changes to improve the environments of children and prevent environmental illnesses.
Health and environment professionals have a critical role to play in stimulating and maintaining changes that will ensure children's health.

- At the patient level it is important to consider if a child’s signs and symptoms might possibly be caused by food poisoning? Are there any others who have been ill in the child’s family?

- Health care providers should be alert and detect “sentinel” cases of foodborne disease. Their detection and study will be essential for developing, proposing and supporting community-based interventions. Publication of cases and research studies allows the communication of knowledge and experience that will benefit other communities and countries.

- It is important to inform and educate patients, families, colleagues and students about the causes of foodborne diseases, their impact on children and pregnant women and on how to keep food safe.

- Finally, we must all become vigorous advocates for the protection of children's food from biological and chemical contaminants. It is important to promote food safety message to children (and pregnant women!).

- Professionals with understanding of both health and the environment are powerful role models. Their attention to food safety will be noticed by patients and communities.
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