Poland, Spain and former Yugoslavia (Hubalek and Halouzka 1999; Lundström 1999; Hrnjakovic-Cvjetkovic et al. 2006). In addition to humans, West Nile virus has also been isolated from horses with encephalomyelitis in France, Italy and Portugal (Jourbert et al. 1970; Filipe 1972; Cantile et al. 2000). Antibodies have been detected in other domestic mammals, *e.g.* bovids as well as in wild mammals, *e.g.* mice, bats and even in the water snake, *Natrix natrix* (Aspöck 1996).

The outbreak of West Nile fever in North America is remarkable. West Nile fever first appeared on this continent in New York in the summer of 1999 when 62 cases and seven fatalities were recorded. During the next 5 years, it spread across the country. In 2003, 9,862 cases and 264 fatalities were recorded in 46 States. Since that time West Nile fever occurred regularly in more than 40 States with thousands of infected people and fatality rates of 2.7–4.1% (CDC 2008).

In the USA West Nile virus has dramatically reduced populations of several common bird species, including robins (*Turdus migratorius*), chickadees (*Parus atricapillus*) and especially crows (*Corvus brachyrhynchos*) which have declined in some regions by 50%. Sixty two mosquito species belonging to a wide range of genera have been found positive for West Nile virus in the United States since 1999 (Reisen et al. 2004). Besides mosquitoes, West Nile virus has also been isolated from ticks. The role of ticks in the transmission cycle of the virus is not understood so far (Eldridge and Edman 2000).

3.2.3 Bunyaviridae (Bunyavirus)

Bunyaviridae are vector-borne viruses with the exception of Hantaviruses, which are transmitted through aerosol contact with mice feces. There are five genera currently recognised in the family. In addition to topsoviruses, which mainly infect plants, *Bunyavirus*, *Hantavirus*, *Nairovirus* and *Phlebovirus*, infect animals. Only the genus *Bunyavirus* includes the viruses which are transmitted by mosquitoes to humans (exception Rift Valley fever, a *Phlebovirus*, which can also be transmitted by mosquitoes). The genome consists of a negative-stranded RNA with three segments.

Three groups of bunyaviruses have been recorded, namely the California group including the California encephalitis, Inkoo, La Crosse encephalitis, Tahyna, Snowshoe hare, Trivittatus and Jamestown Canyon viruses, the Bunyamwera complex including the Bunyamwera, Batai and Cache Valley viruses, and the Turlock group including the Lednice virus only in Europe (Lundström 1999; Eldridge and Edman 2000).

3.2.3.1 The California Serogroup

Viruses of the California group need mammals as amplification hosts (Lundström 1994, 1999; Aspöck 1996). Antibodies have been detected in wild and domestic mammals such as hares, rabbits, bovids, cervids (reindeer), and in carnivores as well as in hedgehogs (*Erinaceus europaeus*). Humans are also susceptible, infection of this serogroup in humans include mild infections to severe CNS diseases such as encephalitis or involvement of the respiratory system. From the public health point of view, the La Crosse (in North America) and the Tahyna virus (in Europe) are the most important viruses (Calisher and Karabatsos 1988; Lundström 1999, Eldridge and Edman 2000).

California Encephalitis Virus

This virus was first detected from *Ae. melanimon* mosquitoes from the Central Valley in California and later from *Oc. dorsalis* from Utah (Reeves 1990; Smart et al. 1972). Antibodies of the virus have been isolated from many mammals such as raccoons, skunks, opossums and woodrats. Infected humans may develop encephalitis.

Inkoo Virus

The Inkoo virus is circulating widely in Northern Europe. Although discovered 40 years ago little is known about the disease associations and immune response in humans (Putkuri et al. 2007).

La Crosse Encephalitis Virus

La Crosse virus is another important arbovirus in North America (following West Nile and St. Louis virus). It causes febrile illnesses accompanied by fever,

headache, vomiting, nausea, lethargy and coma. The virus is perpetuated in an enzootic cycle involving mosquitoes such as the tree-hole mosquito *Oc. triseriatus* and small mammals such as squirrels. The virus can be transmitted transovarially by mosquitoes (Watts et al. 1973). Approximately 70 cases are reported each year.

Tahyna Virus

The Tahyna virus is widespread in Europe and Asia and also detected in Africa (Traavik et al. 1978; Aspöck 1979; Pilaski and Mackenstein 1985; Danielova 1992; Lundström 1994; Eldridge and Edman 2000). Infected people develop influenza-like symptoms which can lead to morbidity. It has frequently been isolated from *Ae. vexans*, but also from other species such as *Ae. cinereus*, *Oc. sticticus*, *Oc. cantans*, *Oc. flavescens*, *Oc. caspius*, *Cs. annulata*, *Cx. modestus*, *Cq. richiardii* (Lundström 1994; Aspöck 1996) and even in biting midges *Culicoides* spp. (Ceratopogonidae) (Halouzka et al. 1991). Danielova and Ryba (1979) proved in experiments that the virus can be transmitted transovarially in *Ae. vexans*. Therefore, it can be assumed that the virus overwinters within the eggs and with the mass development of *Ae. vexans* after spring floods, the virus circulation starts again. Virus overwintering in females of *Culiseta* spp. and *Culex* spp. seems to be of minor importance (Chippaux et al. 1970). Antibodies have been detected in many mammals, such as rabbits, wild boars, deer, cattle, swine and foxes. They serve as reservoirs for the virus and do not develop signs of illness.

Snowshoe Hare Virus

Snowshoe hare (SSH) virus has been reported from the northwestern USA, Alaska and Canada. As the name suggests, the Snowshoe Hare (*Lepus americanus*) is thought to be an important host, but evidence of infection has been found in many wild species such as rodents, carnivores, ungulates as well as in domestic species – chickens, dogs, horses and cattle. Many different species of mosquitoes can become infected and transmit the virus. These include many species of the genera *Ochlerotatus* and *Aedes* as well as the species of *Culiseta* and of *Culex*. Most isolations of this virus have been from snowpool mosquitoes. The virus can be transmitted transovarially and may also persist in cold weather. Disease in humans takes the form of infection and inflammation of the brain such as meningitis and encephalitis (Fauvel et al. 1980). Some cases of clinical illness due to SSH virus probably go unrecognised. However, it appears that infection is much more common than the disease itself.

Trivittatus Virus

This virus occurs in North America and can cause disease with CNS symptoms. Antibodies have been found in rabbits, squirrels, opossums and raccoons. The vectors are *Oc. trivittatus* and *Oc. infirmatus*, other species belonging to the genera *Culex* and *Anopheles* may be involved (Pinger et al. 1975).

Jamestown Canyon Virus

This virus has been involved in a few cases of human disease including encephalitis. Besides humans, large mammals such as deer and other cervids and domestic livestock can be infected. Snowpool mosquitoes such as *Oc. tahoensis* and *Oc. punctor* are the primary vectors (Eldridge and Edman 2000).

3.2.3.2 The Bunyamwera Complex

Bunyamwera Virus

This virus occurs in Africa where it was first isolated in mosquitoes from Uganda. Infected humans develop a febrile illness, including headache and anthralgia. Besides humans, the virus has been found in a wide variety of mammals, including goats, sheep and rats (Eldridge and Edman 2000).

Batai Virus

The Batai virus (strain: Calovo virus) is mainly transmitted by *An. maculipennis s.l.* (Bardos and Cupkova 1962). However, some isolates have also been obtained from *An. claviger*, *Cq. richiardii* and *Oc. communis*

(Francy et al. 1989; Traavik et al. 1985). It can be assumed that the virus overwinters in hibernating anopheline females. Following infection, humans can develop febrile disease with bronchopneumonia, catarrh and gastritis (Sluka 1969). However in Europe, Batai virus antibodies are usually found in less than 1% of the human population (Lundström 1999). Bovids are often infected with Batai virus. Antibodies have also been detected in pigs and deer; birds are not important for the virus circulation. This virus has been reported from several European countries, *e.g.* Finland, Sweden, Germany, Austria, former Czechoslovakia and Yugoslavia (Lundström 1999).

Cache Valley Virus

Cache Valley virus may be responsible for defects in human and animal foetuses as well as for a human case of haemorrhagic disease in the USA. The virus has been isolated in many mosquito species belonging to the genera *Culiseta*, *Aedes*, *Ochlerotatus*, *Psorophora* and *Anopheles*.

3.2.3.3 The Turlock Group

Lednice Virus

The Lednice virus has been isolated from *Cx. modestus*. It is likely that the virus is transmitted vertically in the *Culex* population. Only rarely are vertebrates, mainly birds, infected (Aspöck 1996; Lundström 1999). Antibodies have never been found in humans or wild mammals, except in two hares (Wojta and Aspöck 1982), so the Lednice virus seems to be of no epidemiological importance.

3.3 Filariasis

In the tropics, lymphatic filarial diseases affect an estimated 120 million people in 80 countries throughout the tropics and subtropics of Asia, Africa, the Western Pacific, and parts of the Caribbean and South America. Most of the infections, about 90%, are caused by *Wuchereria bancrofti*. In Asia, the disease can also be caused by *Brugia malayi* and *B. timori*. An estimated 905 million people are directly exposed to the infection transmitted by various genera of mosquitoes, the most important being *Cx. p. quinquefasciatus* and *Mansonia* spp. (Eldridge and Edman 2000). One-third of the people infected with the disease live in India, one third are in Africa and most of the remainder are in South Asia, the Pacific and the Americas. In tropical and subtropical areas where lymphatic filariasis is well-established, the prevalence of infection is continuing to increase. A primary cause of this increase is the rapid and unplanned growth of cities which result in break-down in environmental sanitation which usually creates numerous breeding sites for the mosquitoes that transmit the disease.

Lymphatic filariasis is thought to have affected humans for approximately 4,000 years. Artifacts from ancient Egypt (2,000 B.C.) and the Nok civilization in West Africa (500 B.C.) show possible "elephantiasis" symptoms. The first clear reference to the disease appears in ancient Greek literature, where scholars differentiated the often similar symptoms of lymphatic filariasis from those of leprosy.

Human filarial nematode worms have a complicated life cycle, which primarily consists of five stages. Following mating, the female worm produces millions of microfilariae measuring 244–296 μm by about 10 μm. They are sheathed and have usually nocturnal periodicity which is an adaptation to the biting habit of the vector. The microfilariae migrate into lymph and enter the blood stream reaching the peripheral blood. A mosquito ingests the microfilariae during a blood meal. After ingestion, the microfilariae lose their sheaths and penetrate through the wall of the proventriculus and cardiac portion of the midgut to reach the thoracic muscles of the mosquito. There, the microfilariae develop into second-stage larvae and subsequently into third-stage larvae. This usually takes 7–21 days. The third-stage larvae migrate through the haemocoel to the proboscis of the mosquito, ready to enter the punctured skin following the mosquito bite (Fig. 3.3). During the next months, up to a year, the larvae moult through two more stages, maturing into to the adult worm that commonly reside in the lymphatic system of humans. They live for 4–6 years, producing millions of immature microfilariae that circulate in the blood.

Most of the symptoms of filariasis are caused as a consequence of the adult worms living in the lymph system in the network of nodes and vessels that maintain the delicate fluid balance between the tissues and blood and are an essential component for the body's