Chapter 5
The Epidemic Process in Zoonoses and Sapronoses

This chapter could also be called eco-epidemiological basics or background information for zoonoses and sapronoses. Epidemiology is the study of the process of the origin and spread of transmissible (communicable) infectious diseases of man, and their control. The modern conception of epidemiology is broader in that it also includes non-infectious diseases (such as diabetes, heart attack, cardiovascular diseases and carcinomas) and variables that influence their distribution in the human population. In both the classical and modern conception of epidemiology, these factors include variables concerning the host (age, sex, nutrition, occupation), the agent (virulence, antigenic variability), and the environment (chemical factors, contamination, emissions, temperature, precipitation and humidity, illumination, ionising radiation, noise etc.). Epidemiological data are then analysed, and the results of these studies can then be used for the prevention and control of these human diseases. Epizootiology is characterized analogically but relates to animal diseases. In general, these two disciplines should not be differentiated; already Rudolf Virchow in the middle of nineteenth century wrote: “Zwischen Tier- und Menschenarzneikunde ist oder sollte wissenschaftlich keine Scheidengrenze sein”. This is in line with the present approach called “One Medicine, One Health Concept” (including epidemiology). However, there are some additional characteristics specific for the “epizootiology”, such as, for example, turnover of the animal population (herd), hygienic parameters of breeding, or methods of control of animal diseases including zoonoses (culling of groups or whole herds affected with dangerous diseases).

According to geographical distribution, the intensity and frequency of infectious diseases, their occurrence can be described as:

- **sporadic** (single cases without any obvious connection);
- **familiar** (cases within a family: e.g., alimentary infections with TBE);
- **epidemic/epizootic** (outbreak: an increased or mass occurrence of cases in a particular time and space);
- **pandemic/panzootic** (mass occurrence of a disease in many countries or continents);
- **endemic/enzootic** (a long-term or permanent occurrence of a disease or its agent in a certain locality or area, for instance in a natural focus).
Epidemics/epizootics can be explosive (with a swift onset, an exponentially increasing number of cases and then a precipitate decrease of cases) or prolonged, and can be classically (and best) described in the form of the epidemic curve (i.e., a frequency histogram with the number of cases vs. time intervals). A number of diseases (especially some viral anthroponoses) occur in epidemic cycles with intervals varying according to the aetiological agent. The inter-epidemic interval is the period in which outbreaks or new cases of a particular disease do not occur.

5.1 Characteristics of the Epidemic Process

The epidemic process is an evolutionarily stabilized mechanism consisting of three phases: (1) excretion of the agent from the host’s organism (i.e., the source or donor of an infectious disease); (2) transmission of the agent; (3) its entry into a susceptible host (recipient). Contrary to the infectious process (related to an individual host level), the epidemic/epizootic process concerns the level of a population. [Analogically the disciplines of epidemiology and infectology differ from each other, even though a clear distinction between both subjects is sometimes difficult to make].

5.1.1 The Source of Infection

The source of zoonotic diseases is a vertebrate animal (donor), excreting the microbial agent during the contagious phase, sometimes being without any clinical symptoms but, more often, during the period of fully developed clinical signs. The excretion mechanisms include:

– urination (hantaviruses, leptospires),
– defecation (Salmonella, Giardia),
– regurgitation (the production of pellets, e.g. in raptors and owls: Mycobacterium avium),
– salivation (rabies virus),
– expectoration (coughing: e.g. Nipah or SARS viruses),
– bleeding (e.g. Lassa, Ebola or CCHF viruses),
– lactation (milk-borne zoonoses TBE, brucellosis, bovine tuberculosis),
– via pus (glanders).

In sapronoses, the source of infection is an abiotic substrate (e.g. soil or water in some visceral mycoses, atypical mycobacterioses or legionellosis), in which the agent lives as a saprophyte. However, the abiotic substrate or environment in general cannot be regarded as the source of an infectious disease when the microbe originating from an animal just contaminates and/or persists in the substrate without replication; in that case the source of infection is the particular animal.
A carrier of an infection is an individual that carries and excretes the infectious agent without having clinical symptoms at that time. The carrier can be:

- healthy or asymptomatic;
- in the incubation period of the disease (dog – rabies);
- in the convalescent phase of the disease;
- in the chronic state of the disease, with persisting infection (man – typhoid).

Carriership is epidemiologically a very important factor due to the asymptomatic, discreet pattern of the host. Carriership can be relatively short-term or long-term (even lifelong), and excretion of the infectious agent can be regular or irregular to erratic.

It is important to differentiate between the source and the reservoir of a disease. The latter is a vertebrate or invertebrate animal species (in zoonoses) or a microhabitat in the environment such as soil, rhizosphere, an organic substrate, or water (in sapronoses) in which the agent thrives also in an interepidemic period.

5.1.2 The Transmission Mode of the Infectious Disease

The transmission mode of an infectious disease is the means by which transfer of the infectious agent goes from the source (e.g., a vertebrate donor host) to a susceptible host (recipient), including all contributing factors. This transfer can be either direct or indirect contact, the latter mediated by contaminated excrement, food, animal products, arthropods, etc. Epidemiologists classify the transmission modes (Fig. 5.1) into four categories, as:

(a) contact (direct transmission: contact diseases, including perinatal infections);
(b) inhalation (via air, aerogenically: generally the group of respiratory, air-borne infectious diseases);
(c) ingestion (food-borne and water-borne alimentary, gastrointestinal diseases);
(d) inoculation (group of infections transmissible by haematophagous arthropods, and some nosocomial – acquired in hospital – or iatrogenic infections, i.e., acquired inadvertently during diverse medical procedures and treatments such as injections, infusions, blood transfusions or operations).

Categories (b) to (d) are also called indirect transmission, accomplished through diverse factors. Sometimes another additional group of indirect transmission is detached as so-called contaminative transmission, usually in infectious skin diseases; in this transmission for example underwear, bed linen, baths or medical instruments are involved.

The common mode of spread in communicable diseases in the population is horizontal transmission (i.e. from one individual to another), while less frequent is vertical transmission from female to descendants. Transplacental transmission is a specific means of transmission known in mammals when the pathogenic
microorganism is transmitted from the infected mother to the embryo during intrauterine development; this can cause abortion, premature birth, stillbirth, malformations, and innate diseases. These pathological effects have been observed in some zoonoses such as brucellosis, listeriosis or toxoplasmosis. The spread of the agent from mother to baby is also possible during lactation (brucellosis, Q-fever).

Tenacity (resistance of the pathogenic agent outside the host or vector organism) under different circumstances has great importance in epidemiology. Many pathogens survive for a long time in animal products such as meat, milk, eggs, skin and its adnexes (mycobacteria, listeriae, coxiellae, brucellae, salmonellae, *Clostridium botulinum*, *Bacillus anthracis*, *Trichophyton* spp., *Toxoplasma gondii*), in excreta (salmonellae, mycobacteria, leptospirae, brucellae), and also in water (salmonellae, leptospirae, atypical mycobacteria, francisellae, yersiniae) and soil (fungi, *Bacillus anthracis* spores). Sporulating microorganisms are, in general, much more resistant to refractory external conditions than vegetative forms and non-sporulating microbes.

Some very important potentially microbistatic or microicide environmental factors, are:

- temperature (*Listeria monocytogenes* grows even at 4°C!);
- humidity (most pathogens are not very sensitive to drying, but several, e.g. *Fusobacterium necrophorum*, is very sensitive);
- light and ultraviolet radiation (*Mycobacterium bovis* is inactivated in direct light within 2–3 h, while in diffuse light much later, 30–40 h);
- pH (for instance, most arboviruses cannot tolerate pH values other than neutral while *Mycobacterium bovis* survives as long as 20 min in 10% sulphuric acid!);
– oxygen (toxic for anaerobic bacteria – clostridia);
– disinfectant compounds, antibiotics and other microbicidal substances.

Acquired resistance to antibiotics and chemotherapeutics occurs in a number of bacterial (methicillin-resistant *Staphylococcus aureus*, vancomycin-resistant *Enterococcus faecium*) and protozoan (chloroquine-resistant *Plasmodium falciparum*) species.

### 5.1.3 Susceptible Population of the Host

Factors influencing susceptibility or resistance of a vertebrate population against an infection are, for example:

– age structure of the population;
– “herd immunity” (occurs when the proportion of immune individuals in a population or herd is sufficient to stop the spread of an infectious disease to unprotected individuals);
– physiological state of the population (malnutrition, insufficient supply of vitamins and trace elements);
– stress conditions in the population (physical, psychological);
– concurrent other diseases in the population.

### 5.2 External Factors in the Epidemic Process

These factors can be divided into socio-economic (acting within human society) and environmental/natural (physical, geographical, biotic) variables. The effect of both these groups of factors is especially pronounced in diseases with natural focality, and in emerging infectious diseases.

#### 5.2.1 Socio-Economic Factors

Socio-economic (or social) factors play, of course, principal role in anthroponoses, but they are also important in zoonoses and partially in sapronoses. These factors involve:

– the density of human population in certain area;
– social and hygienic conditions (life style and level): trench fever (*Bartonella quintana*) in battlefields, refugee camps (Rwanda) or in homeless people (southern France, Seattle and Moscow);
– close contact between humans and domestic animals: “mixing” areas in southeast Asia for avian, swine and human influenza A viruses;
– a collective style of life: communal eating habits (company canteens, fast-food places: hamburgers contaminated with *E. coli* O157, or chicken meat with *Campylobacter jejuni*) and accommodation patterns;
the degree of countryside urbanisation (expansion of towns, especially in tropical regions); formation of “slums” with good conditions for epidemic outbreaks (e.g. malaria, yellow fever, dengue, Chagas disease, plague etc.);

— “suburbanization”, i.e. building of detached houses in peri-urban forested areas – e.g. in Connecticut (USA: annual incidence of Lyme borreliosis here up to 1,000 per 100,000 population, while in Central Europe only about 30–50 per 100,000); or in forested districts of Novosibirsk (presenting a very high morbidity with RSSE);

— the colonisation of new lands (“pioneers”) and the following anthropogenic impact in ecosystems involving building of settlements, extensive landscaping (yellow fever during building of Panama Canal, Oroya fever during railway construction in Venezuela, RSSE at construction of the Trans-Siberian Railway), deforestation (scrub typhus, Nipah fever associated with the movement of reservoir fruit bats to farmland after the cutting down of trees, malaria in Brazil), but also reforestation (LB in eastern USA);

— the construction of water reservoirs, irrigation of farmland (schistosomiasis in Asuan, mosquito-borne diseases) and draining marshes;

— unintentional creation of new, artificial breeding places for mosquito larvae such as water-containing and for insects accessible pots, barrels, tanks, used tyres, sewage systems, etc.;

— rapid international transport and commerce: importation of new pathogenic agents, invertebrate vectors and vertebrate reservoirs (e.g. “airport malaria”; import of used tyres or decorative plants like lucky bamboo (*Dracaena*) → dispersal of Asian mosquitoes *Aedes albopictus* and *Ae. japonicus* to America, Africa and parts of Europe; yellow fever spread from Africa to America with the slave trade together with the vector mosquito *Aedes aegypti* on ships);

— the markedly increased mobility and migrability of the human population for business (each year >500 million dealers and merchants fly to foreign destinations), tourism and education, the immigration of workers from abroad;

— expanded domestic tourism connected with potential entering natural foci of infectious diseases (TBE, LB, etc.); tourism to foreign countries, foreign trade fairs and pilgrimage with potential risk of acquiring an “exotic” or other infectious zoonotic or sapronotic disease (Lassa, Ebola); “adrenaline tourism” (leptospirosis in water sports);

— leisure time activities (hunting at home and abroad, safaris, and the collection of mushrooms and forest berries), leading to an enhanced contact with vectors of diseases;

— an increased density of pets and companion animals in the human population;

— the expansion and intensification (concentration, specialisation) of agriculture (e.g. this led to enhanced incidence of leishmaniasis in the Caucasus and Nepal due to overpopulation of burrowing rodents; *Apodemus agrarius* prefers rice fields in eastern Asia → increased incidence of HFRS; new irrigated rice paddies in south Asia → Japanese encephalitis; integrated duck and swine farms in China → risk of origin of influenza pandemic strains);
the processing and consumption of animal products and animal waste: for instance, BSE in Great Britain originated from the consumption by cows of meat-bone meal from sheep with scrapie, and led to the follow-up outbreak of a new variant of CJD in humans;
the movements of herds and flocks of domestic ruminants to new pastures, and nomadism;
the import and export of domestic animals, their products and foods of animal origin (eggs – salmonellosis);
the domestication of animals (mainly in the past), deer farming in many parts of the world (at present): risk of brucellosis, bovine tuberculosis or paratuberculosis;
the import and breeding of exotic animals in zoos, safari parks, for research or private use;
the occupational risk of zoonotic and sapronotic diseases especially for: animal breeders and keepers, vets, butchers and slaughterhouse workers; forest workers (ixodid tick-borne diseases); casual labourers (pulmonary mycotic infections); medical laboratory workers and researchers;
nosocomial/iatrogenic zoonotic infections (viruses Ebola, Lassa, CCHF) at blood transfusions (HIV, malaria, CTF, babesiosis etc.) and organ transplantations;
xenotransplantation (contaminated organs of animals that are transplanted to humans), animal cell cultures used for preparation of vaccines: for instance, in pigs hepatitis E and retrovirus infections occur asymptotically;
drug abuse (HIV, hepatitis, anthrax);
cosmetic operations (piercing, tattooing);
insufficiency or absence of health prevention (including health education) and care, decline of health system infrastructure;
social disasters and stress (wars, refugee camps, famine).

We can say with certain degree of exaggeration that a common denominator in nearly all socio-economic factors in zoonoses and sapronoses is the globalisation of: economics, the transport of goods, animals, and persons, tourism and recreation, animal and plant production, life style, landscaping and so on. An appropriate metaphor has often been used is that the world is becoming a “global village”.

5.2.2 Environmental (Natural) Factors

The environmental factors that are not associated with human activity are principally diverse ecological variables that determine or affect the circulation of pathogenic agents. They involve the factors: (a) abiotic, i.e. geomorphological, geological, hydrological, pedological (soil character and structure), climatic and meteorological (actual weather conditions); (b) biotic. i.e. vegetation and fauna. This complex of environmental factors influences for example the geographical distribution of zoonotic (in connection with the distribution of reservoirs, amplifying hosts, and potential vectors) and sapronotic agents.
Among the abiotic factors, generally the most important is climate (temperature, precipitation), and then latitude, altitude and relief (geomorphology influences, e.g., mesoclimatic and microclimate). For instance, a significant correlation between the El-Niño Southern Oscillation (ENSO) activity in the Pacific Ocean and an increased incidence of certain infectious diseases (cholera, malaria, hantavirus pulmonary syndrome) in widespread regions during 1991–1993 was reported. There are substantiated fears that global warming could affect the geographical distribution of some arthropod-borne diseases as malaria, dengue, or leishmaniasis. In the analogous climatic system of North Atlantic Oscillation (NAO), which markedly affects the weather in Europe, its correlation with incidence of zoonoses and sapronoses has not yet been proven.

Abiotic environmental conditions also determine the seasonality of many infectious diseases, especially those transmitted via invertebrate vectors (e.g. TBE, LB) – this is caused by the seasonal distribution (phenology) of their vectors. For the seasonality of some vectors (mosquitoes) increased precipitation in certain periods of the year is necessary, forming at least periodic pools or wetlands favourable for development of the vectors. Environmental temperature can markedly influence the replication rate of viruses in insect vectors.

Natural disasters are also abiotic factors; they are meteorological (hurricanes or tornados), hydrological (floods) or geophysical (earthquakes, extensive landslides or tsunamis). For instance, the 1994 earthquake near Los Angeles caused the increased incidence of pulmonary mycoses (170 human cases of coccidioidomycosis and histoplasmosis) – their agents sporulate in the soil, and the spores were aerosolized during the event. Shortly after floods populations of blood-sucking insects, especially mosquitoes, usually peak, with potential subsequent outbreaks of mosquito-borne diseases (in tropical countries dengue and malaria), and also other zoonoses and sapronoses because of disruptions in water, food and power supply: e.g., colibacillosis (enteropathogenic Escherichia coli), salmonellosis, melioidosis (in tropics), leptospirosis, tularaemia, giardiosis and cryptosporidiosis.

Biotic factors, influencing epidemic (and epizootic) process, are in particular:

- size, density and development of populations (population dynamics) of both vertebrate hosts (reservoirs) of diseases and invertebrate vectors (dangerous "gradations");
- bionomics and behaviour (the existence of nesting colonies, common roosting sites and gathering places, synanthropism), and phenology (seasonality) of hosts and vectors;
- mobility ("home range") and migration (of birds and bats, invasions and vagrancy) of hosts and vectors;
- herd immunity in hosts populations;
- stress factors (malnutrition or overpopulation) in host populations;
- pattern and type of vegetation;
- intrinsic changes of pathogens (virulence, host and vector ranges).

A very important ecological factor in the spread of many zoonoses is the population dynamics of vertebrate hosts, and namely their overpopulation, which
can lead wild vertebrates to approach human dwellings (especially in cold seasons of the year). For instance, the overpopulated common hamster (*Cricetus cricetus*) in eastern Slovakia in 1972 (the population density was 200 ex./ha) entered farmyards and human dwellings and caused tularaemia cases in humans.

Bird migration can play a role in the spread of microbial zoonotic pathogens, in two ways: (i) migratory birds are hosts of these agents; or (ii) they transmit infected ectoparasites – vectors. According to qualified estimates, every year about half a billion birds migrate from Europe to Africa and back, and a part of them are infested with ticks. Hoogstraal and Kaiser examined 1826 birds during their northward migration in Egypt in the springs of 1960 and 1962: ixodid ticks were found on 10% individuals (about 90% of the ticks were the African subspecies *Hyalomma marginatum rufipes*). African ticks were also observed on birds in Bulgaria (*Amblyomma variegatum, A. hebraeum*) and in Azerbaijan (*A. lepidum*), and *Hyalomma marginatum* sporadically in Czechland and Finland. Imagoes of African ticks *A. variegatum, A. hebraeum* and *A. gemma* were detected on domestic animals in southern Europe (Italy, France, Bulgaria, Crimea) as a consequence of importation of their larval stages with birds. A majority of these exotic ticks cannot finish their developmental cycle under environmental conditions in Europe, but some of them could theoretically infect local vertebrate hosts and give an origin for new natural foci of infections. In addition to birds, also some bats migrate for longer distances (e.g., *Miniopterus schreibersii*). Further, even insect vectors can be imported with air currents under specific meteorological conditions (e.g. biting midges *Culicoides* infected with veterinary important arboviruses bluetongue or African horse sickness).

In some diseases (and their agents), their general association with environmental characteristics is so close and specific that it is possible to predict their distribution in new areas, using biogeographical indicators (isotherms, isohyetes, certain plant communities or collections of indicator plant and animal species). Another approach is the “remote sensing” of the Earth from satellites (e.g. Landsat); this technique was used to monitor arthropod-borne diseases in Africa (RVF, malaria and trypanosomiasis), Europe and North America (TBE and LB) and South America (malaria and Chagas disease). The most utilized data from the satellites is the “normalized difference vegetation index” (NDVI). Data received from satellites are combined with data from the geographical information system (GIS), and make it possible to model risk maps for particular infection and area (e.g., risk of human infection with LB based on the distribution of *Ixodes scapularis* in North America).

### 5.3 Natural Focality of Diseases

The concept of natural focality (also translated as “nidality”) of diseases was first presented by E. N. Pavlovsky during a 1939 meeting of the U.S.S.R. Academy of Sciences, in a paper entitled “On the Natural Focality of Infectious and Parasitic Diseases”. The idea of this doctrine is based on the fact that the aetiological agents of a number of infectious diseases circulate among free-living vertebrates and blood-sucking arthropods in nature absolutely independently of man, being an
The Epidemic Process in Zoonoses and Sapronoses

Man can acquire the disease when entering the natural focus after contact with the host or the vector of the disease, but he/she is a “dead end” host of the enzootic cycle. The natural foci of many diseases are closely related to specific ecosystems or biomes. For instance, foci of TBE/R SSE and HFRS (bound to taiga, and mixed forests of the mild Eurasian zone), sandfly fever and Mediterranean tick typhus (macchia ecosystem), CCHF (xerothermic pastures), cutaneous leishmaniasis and tick recurrent fever (desert and semidesert ecosystems), KFD and scrub typhus (tropical rainforest). Diseases with natural focality are in fact endemic and enzootic zoonoses or sapronoses, and their study is a sort of landscape epidemiology/epizootiology.

Principal components of natural foci of infections are:

(a) the aetiological agent of the disease (the microbial pathogen);
(b) wild vertebrates – hosts of the agent (donor, recipient, or even reservoir of the agent);
(c) haematophagous arthropods (mites including ticks, insects) – vectors;
(d) the habitat and environmental factors, enabling permanent circulation of the agent.

Condition (c) need not be fulfilled in sapronoses and some zoonoses with natural focality; e.g. haemorrhagic fevers caused by Hantaan, Ebola, Marburg, Junin, Machupo and Lassa viruses, and a number of others, not transmissible by invertebrate vectors, are also classified as diseases with natural focality.

The basis of a natural focus is an ecosystem, a geobiocenosis, formed by a biocenosis (plant and animal communities) and a biotope (abiotic environmental conditions). During investigation of a natural focus, the study should involve not only the autecology of principal hosts (reservoirs) and vectors, but also their synecology, interrelationships and association rate with the habitat. Indicators of a natural focus can sometimes be characteristic features of the landscape (relief etc.) or some components of biocenoses, that could directly or indirectly reflect the presence of the agent, and make it possible to help unveil the focus in the field. Ecotones (dividing lines between two different habitats or ecosystems, e.g. forest/pasture) are very important elements in the natural foci, being contact sites for different vertebrate species from both habitats with occasional exchange of their ectoparasites and also pathogens (B. Rosický).

The natural focus of disease (NFD) is geographically defined as the territory including one or more landscape types where permanent circulation of the aetiological agent occurs without it being introduced externally. In that sense, NFD is a territorial unit, and its borders can thus be marked on a map. It has a spatial structure, being formed of a “nucleus” (a proper seat of the agent that can survive there long-term even in the epizootic period), and the surrounding “coat” appearing during increased epizootic activity of NFD. The least space in which a pathogenic agent can long-term survive in a biocenosis used to be designated as an elementary focus. In addition, the biotic structure of NFD is defined and formed by a complex of the agent, hosts, and vectors of the disease.
A very important, though often contradictory, term in epidemiology and natural focality of diseases is the reservoir. According to the modern conception of natural focality terminology (Kucheruk and Rosický 1983), the reservoir of an infectious disease is either an (vertebrate or invertebrate) animal species in zoonoses, or an abiotic environmental component in sapronoses (soil, organic substrate, water), where the agent survives in the interepidemic/interepizootic period.

The host of the agent (a vertebrate) is either primary/principal (secures permanent circulation of the agent), secondary (often involved in the epizootic process) or accidental (does not play a role in the epizootic process). In as far as the host becomes the source of infection of another vertebrate, it is branded as the donor, while the acceptor of the infection is the recipient. A useful term is the “amplifying host”, i.e. that vertebrate host in whose blood the agent replicates in such a manner that it could serve as an effective donor of the agent for a haematophagous vector.

A vector (a haematophagous arthropod able to transmit the pathogenic agent) used to be classified analogically as primary/principal, secondary or accidental. In parasitological terms, the vector is an obligate ectoparasite of a temporary type, and can be associated with different species of hosts in different foci of a disease. For instance, the natural foci of TBE (and some other tick-borne infections) in central Europe can be distinguished (Rosický 1964) as “theriodic” (when the main hosts of adult *Ixodes ricinus* ticks are wild game animals), “boskematic” (when the main hosts of adult *Ixodes ricinus* ticks are grazed domestic animals like cattle, sheep, goats), “mixed theriodic-boskematic”, and “mountain” (the vector might be *Ixodes trianguliceps* tick, a nidicolous ectoparasite of rodents).

The natural foci of a disease can vary in their valence reflecting present activity of the focus, i.e. the intensity of circulation of the agent. The foci are not stable for years, they evolve due to changes in biocenoses that affect fluctuation in valence, decline or origin of the natural foci. For instance, it is well known that a drainage in a landscape decreases activity of natural foci of tularaemia while area (re)forestation increases the valence of LB foci (northeast US states). Nowadays, the most important factor in the evolution of natural foci is not a natural succession of habitats but man with his “anthropic” activity (pasturing, deforestation, reforestation, draining, irrigation, building of water reservoirs, landscaping, etc.) resulting in “anthropisation” of the landscape. We can distinguish eubiocenoses (hardly affected by man), agrobiocenoses (farmland), and anthropobiocenoses (human habitats and urban ecosystem). A more detailed differentiation of countryside according to the land-use rate suggested Rosický and Hejný (1959) for Europe:

(1) natural landscape – practically only the tops of high mountains (no natural foci of diseases occur);
(2) landscape slightly affected by human activity – for instance mountain areas (virtually without haematophagous vectors except for the Mediterranean: natural foci of leptospirosis or, in southern Europe, some arboviroses); examples outside Europe: HPS (North America);
(3) landscape moderately affected by human activity – e.g. flood-plain forests or some less cultivated forests (natural foci of tularaemia or TBE);
(4) landscape markedly affected by man – a major proportion of countryside in Europe (foci of TBE, LB, leptospirosis, etc.);
(5) fully cultivated landscape (farmland: Q fever, brucellosis, tularaemia);
(6) landscape devastated by pasture, air pollution, mining (*Mycobacterium kansasii* infections), exploitation or dumping grounds;
(7) urbanized landscape – the urban ecosystem, consisting of: “city” – pericentre – residential areas – suburban areas. A number of zoonoses occur even in urban biocenoses, e.g. LB (city parks), psittacosis (*Chlamydophila psittaci*), toxoplasmosis (feral pigeons and cats as the source) or dermatophytosis caused by *Microsporum canis* (cat and dog). Pets or “companion animals” (cat, dog, horse, etc.) and synanthropic vertebrates (mouse, rats, feral pigeon, etc.) play a considerable role in their circulation in urban cycles.

For examples of natural foci of zoonotic diseases, see Photos 5.1–5.49.

Epidemiologically important aspects or factors in the land use are, for example:

- global changes of biotopes;
- the formation of new biotopes (water reservoirs, pastureland, deforested or reforested areas etc. – LB);
- ecotones (balks, windbreak tree lines – emmonsiosis);
- the succession of biocenoses in anthropic biotopes (slag heaps etc. – LB);
- the synanthropisation of animals (exoanthropic vs. [eu]synanthropic animals);
- game breeding for profit (various deer spp.);
- the introduction of exotic mammals (e.g., mouflon);
- nomadism (migration of animal herds: still practiced in many tropical and subtropical countries);
- the conservation of original habitats in nature park areas – reservations (in which elementary natural foci of diseases could persist – e.g., TBE, tularaemia).

### 5.4 Epidemiological Examination in the Focus of an Infectious Disease

The focus of an infection is (unlike the natural focus of infection) a place where the disease spreads from. Techniques that epidemiologists use for analysis of an outbreak are descriptive and analytical.

### 5.4.1 Descriptive Epidemiological Methods

They aim to find answers for three principal questions: *Who? Where? When?* (Epidemiology can be regarded, in fact, as a sort of detective story).

(1) *Who?* Data about patients: age; sex; ethnic group; occupation; anamnesis.
(2) *Where?* Description and characterization of the place of infection: geographical location of the cases (entered on a map); the character of the environment
(natural and social conditions: urban-rural; agricultural-industrial; presence of potential zoonotic and sapronotic sources).

(3) (When?) Time data: date, duration and dynamics of the individual disease and outbreak (an epidemic curve which can be explosive or protracted); determination of the incubation period and probable time of infection in individual cases; seasonal dynamics of the disease (graph); long-term trends of the disease; epidemic cycles.

These descriptive epidemiological methods were first, and in an exemplary way, used by John Snow in his search of the infectious source of cholera in London, 1854 (Photos 5.50 and 5.51).

**Basic Statistical Indices in Epidemiology**

These indices play an important role in comparative descriptive epidemiology, and most frequently involve the following coefficients.

Morbidity is the ratio of the number of sick persons to the number of all persons living in the area; usually it is given as the number of sick persons per 100,000 population per year. So-called specific morbidity is only related to a certain, well defined group (cohort) of residents characterized by for example age, sex, occupation, or related to certain period (a week, decade, month, season) or locality.

Prevalence is the number of all sick persons in a population at certain time (e.g. as for 1st July, point prevalence) or interval (interval prevalence); this index is useful especially for chronic diseases (such as tuberculosis) the incidence (annual increment) of which can be low though they are sufficiently widespread, or for those infectious diseases where it is difficult to estimate their beginning. Prevalence relates to all cases of the disease – new and old.

Incidence is the number of new cases in a certain period (e.g. a year), and can be assigned to the number of all inhabitants in certain area as with morbidity. However, incidence only concerns new cases.

Mortality is the ratio of the number of persons that died due to particular disease to the total population in the same area; it is usually given as the number of dead persons per 100,000 population per year. So-called specific mortality is only related to a certain well-defined cohort of residents.

Lethality (fatality rate) is the ratio of persons that died due to certain disease out of all persons ill from that disease (i.e. not all infected!); it is given in percent.

**5.4.2 Analytical Epidemiological Methods**

They aim to prove causality according to the following general algorithm:

(1) supplementary clinical, pathologic-anatomical, microbiological, serological and other examinations in the focus (Photos 5.52–5.62);
(2) definition of spatial and temporal extent of the disease;
(3) identification of the factor in common among the affected persons;
(4) formulation of a hypothesis about the source of the infectious disease.

The association of various variables and conditions with the frequency of a certain disease is statistically tested using $2 \times 2$ or $2 \times n$ contingency tables ($\chi^2$ test, Fisher exact test), parametric or nonparametric correlation coefficients, or so-called “odd ratio” (OR). During these epidemiological analyses it is sometimes necessary to include also control group of persons in addition to the primary group of affected persons/patients (“case and control study”). Epidemiological studies can be divided into prospective (headed from cause to consequence of the disease) and retrospective (headed from consequence of the disease to case). For additional methods useful in epidemiology, see Ahrens and Pigeot (2005).

Serological surveys present a very good method for showing a contact of a population with a particular agent, and retrospective epidemiological analysis. Detection of immunoglobulines of certain classes (and especially the ratio IgM to IgG) offers in a number of diseases means for estimation of their dynamics (IgM are produced in earlier stages of infection than IgG). Serological examinations can be single, repeated or longitudinal. Comparative testing of antibody titres in paired serum samples, taken during acute and convalescent phase of the disease (at an interval of 3–4 weeks), is used as a method for detection of recent infection. Allergic skin tests are another useful and sensitive technique for revealing previous contact of population with particular disease agent.

### 5.4.3 The Epidemiologists’ Activity

It is then based on the results of examinations, and aimed at controlling an acute epidemic situation (isolation and hospitalisation of patients, quarantine, disinfection, disinsection or deratization) or implementation of preventive measures (securing hygienic standards, vaccination, registration of carriers in some diseases). Unlike prevention, prophylaxis presents medical measures intending to achieve specific protection (immunity) of the host organism against the agent or its harmful products (toxins, allergens), and is to be applied before, or very shortly after, the exposure. Prophylaxis involves the use of chemotherapeutics (antibiotics), passive immunization (specific immunoglobulins, antitoxins) or vaccination (active immunisation with a live/attenuated, inactivated, subunit or synthetic vaccine, DNA vaccine or anatoxin). The efficacy of vaccination has been confirmed many times, for example in the control of yellow fever (Photo 5.63), or in vaccination campaign against TBE in Austria, where about 80% population has been immunised.

### 5.5 Epidemiological Surveillance

The term *surveillance* was first used in epidemiology in 1950 in connection with monitoring and control programs for malaria, smallpox and urban yellow fever. The
epidemiological surveillance was recommended by WHO in the years 1968–1969 as a modern approach of controlling infectious diseases. It is a complex epidemiological study of a disease as a dynamic process, including the ecology of the pathogenic agent, hosts, reservoirs and vectors of the disease, as well as the study of the environmental conditions and all mechanisms that affect spread of the disease. In short, epidemiological surveillance is monitoring of the disease and all external variables which can influence its dynamics; the data are collected, stored in a database and continuously evaluated. The final aim of epidemiological surveillance is the control (suppression) of the disease based on knowledge of those factors determining or modifying the epidemiological or epizootiological process.

According to WHO (WHO Tech. Rep. Ser. 682, 1982), “epidemiological surveillance is the process of collection, interpretation, and distribution of information on rates of occurrence of a particular disease to estimate the variation of incidence and prevalence in order to take appropriate action for the control or eradication of the disease”. In short, the outline of epidemiological surveillance could be expressed as “collection → interpretation → distribution → action.” Distribution here means feedback of information for medical workers in the field. The content of the surveillance is: (1) exact and rapid diagnosis of the disease (clinical, pathological and laboratory, including isolation and identification of the pathogenic agent from human, animal and vector samples – see Photos 5.53–5.62); (2) meaningful use of accessible means to control the disease. For instance in zoonoses, concentration on the animal reservoir or vector would be optimal: e.g., rat extermination, vector control, or the use of baited peroral vaccines for wild animals as foxes in the case of rabies.

The presence of a zoonosis in a certain area can be indicated by clinical observation of animals (rabies, RVF, virus encephalitides, WN disease, and hantaviruses), their post-mortem examination, meat inspection (tuberculosis, anthrax), with the use of serological surveillance (SLE in sentinel chickens or sparrows, JE in young domestic pigs, brucellosis in cattle, sheep and goats) and allergic skin testing (bovine tuberculosis), monitoring isolation tests of vectors (e.g. of mosquitoes in American equine encephalitides and other mosquito-borne diseases) and foods of animal origin. Data on overpopulation (very high population densities) of vectors and hosts (especially reservoir hosts: e.g. fox and rabies, rodents in tularemia and hantaviruses like HFRS) are epidemiologically disturbing. The rapid international exchange of epidemiological information, based on WHO, FAO and express media such as ProMED-mail (a program of the International Society for Infectious Diseases) is always of great importance. This information exchange is a part of international “early warning” system and makes possible the “rapid response” activity of epidemiologists and other components. For this purpose, there is also International Classification of Diseases (including zoonoses and sapronoses), and a list of “notifiable (reportable) diseases” which, however, differs among countries, i.e. certain infectious diseases are to be reported only in certain countries. In addition to national epidemiological centres and national reference laboratories, there are international institutions such as WHO, CDC in USA, or ECDC in Europe, which have available a background of expert teams and reference laboratories. For instance,
many programmes concerning epidemiological surveillance of zoonoses have been established and funded by European Commission during the last decade (ENIVD, EDEN, EpiSouth, EpiNorth), others include EpiZone, GeoSentinel, CaribVET or FoodNet.

It is very important to emphasize that the collaboration of a broad and well-coordinated team of experts from different fields (epidemiology, infectology, environmental microbiology, human medicine, veterinary medicine, medical zoology and climatology) is necessary to manage a high-quality epidemiological surveillance system.

The problem of bioterrorism is also connected with epidemiological surveillance. Bioterrorism is defined as a wilful use of microorganisms or toxins from living organisms with the aim to cause disease or death in humans, animals or plants which are essential for mankind. The danger of modern terrorist attacks with microbes were demonstrated in the USA in 2001 with anthrax spores in mail (22 cases, including five fatalities). Because a number of zoonotic and sapronotic pathogens could serve for the production of bio-weapons we cannot avoid this issue. Out of zoonoses, plague, tularaemia, brucellosis, glanders, Q fever, viral haemorrhagic fevers (Ebola, Marburg, Lassa), and viral encephalitides (VEE, WN, SLE, JE) present a potential danger, and out of sapronoses mainly anthrax, \textit{Clostridium botulinum} (toxin), melioidosis, cholera or coccidioidomycosis. Every new outbreak with unclear epidemiological characteristics (unusual clinical cases, indeterminate aetiology or mass outbreak) should be considered also from this perspective. Most important is an established rapid response system acting from the low level – i.e., from an adequately dense and coordinated network of human and veterinary health centres (hospitals, outpatient clinics) and diagnostic laboratories – to the rapid dissemination of information and treatment.

5.6 The Control of Zoonoses and Sapronoses

The struggle against infectious diseases proceeds at three levels: prevention . . . control . . . eradication. The basic step and integrating activity in this struggle is the strategy of epidemiological surveillance.

1. \textbf{Prevention} is the implementation of a series of measures inhibiting illness of humans (or animals) and the origin of outbreaks: conformation to hygienic rules, use of repellents (in arthropod-borne diseases), vaccination, veterinary control at borders, observance of technology rules in the meat, dairy and leather industries, and health education. Also consistent legislation is helpful: search for, and evidence of, germ-carriers, preventive examinations, and a disease reporting system.

2. \textbf{Control} is the implementation of a series of measures decreasing total incidence of a disease, and suppressing an already occurring epidemics. It consists of quarantine (isolation of infected people), medical nursing or hospitalisation in seriously ill patients, accessible medical treatment at local levels (hospitals and diagnostic laboratories), therapy or in animal-hosts reduction of numbers
(elimination/culling of infected or vagrant animals including safe collection and disposal of carrion), safe burial of human victims, safeguarding drinking water, safe removal of waste (rubbish), reduction of arthropod vector populations (by habitat changes, use of insecticides, attractants or biological methods [predators, parasites], and reduction of their fertility), environment decontamination, control of the abiotic environment (in sapronoses) and vehicles (veterinary inspection of foods of animal origin), and zoohygienic measures against the spread of infectious diseases.

Environmentally-friendly techniques of reduction of invertebrate vectors should be preferred to insecticide application. For instance in mosquitoes, the use of larvicide microbial toxin – *Bacillus thuringiensis israelensis* (effective against members of the genus *Aedes*) or *B. sphericus* (effective especially against *Culex* spp.), but also management of water level in particular areas. It is necessary to note that there is a problem with growing resistance of mosquito populations to current adulticide and some larvicide preparations (organophosphates, carbamates, pyrethroids), particularly in Africa.

By analogy, interventions against rodents (rodenticides of higher generations) and other vertebrates – hosts or reservoirs of zoonotic agents – should also be environmentally friendly. The main goal is to ensure that these biocides do not put at risk other, non-target animals (and of course humans) with either direct contact toxicity or in the form of a cummulative effect in food chains.

3. **Eradication** means rooting out the agent of a disease from an area. This necessitates very concentrated, i.e. expensive, procedures including consistent monitoring of the disease combined with vaccination of humans and (in zoonoses) also of animals. In this sense, only one disease has been eradicated globally: smallpox (which is, of course, an anthroponosis).

In all eradication trials the economy of expense vs. final effect plays a decisive (according to the “cost-benefit” analysis) role. This is obvious in for example African malaria. Therefore the modern control of diseases clearly prevails over the attempts of their eradication.