Chapter 8
Epidemiologic Surveillance

Ralf Reintjes and Klaus Krickeberg

8.1 Introduction

Not every topic admits a precise definition but ours does:

Epidemiologic surveillance is the collection, transfer, analysis, and interpretation of information related to cases of diseases, which is done systematically and routinely.

Thus surveillance is to be distinguished from studies set up ad hoc in order to investigate a particular epidemiologic problem. In the present chapter, we restrict ourselves to surveillance of infectious diseases. The information may be in the form of *data* or of statistical *indicators* such as incidences or prevalences. Its *content* can be fairly wide. In addition to general data on infected persons and their diseases, there may be data on symptoms, serological and other laboratory data, data concerning pathogens recovered from patients and patients' behaviour, and information on the presence of vectors as well as on general risk factors.

Epidemiologic surveillance works in many ways but always within a well-defined *system.* Such a system consists of the sources of the information, the mechanisms for collecting and transmitting it, and procedures of analysis. Data originate in the first place in physicians' practices, hospitals, and other health facilities including laboratories, but additional information may flow from various other sources like statistical offices, health insurance, and vector surveillance. Mechanisms for collection, transmission, and analysis vary considerably – both by their organization and by the technical means employed. A surveillance system can operate on a local level, for example, in a city, or on a regional, national, or international scale.

Surveillance is used for monitoring the time trends in the occurrence and distribution of diseases in populations and of factors that may have an influence on them. Information derived from disease surveillance is used for policy decisions regarding immediate interventions, general health strategies, health management, and the structure of the health system. The discovery and management of disease outbreaks,

R. Reintjes (✉)
Department of Public Health, Hamburg University of Applied Sciences, Hamburg, Germany
e-mail: ralf.reintjes@haw-hamburg.de

A. Krämer et al. (eds.), *Modern Infectious Disease Epidemiology*,
Statistics for Biology and Health, DOI 10.1007/978-0-387-93835-6_8,

formerly also called "epidemic surveillance" and described in Chapter 9, is normally based on an existing system of routine surveillance supplemented by special investigations and interventions.

In the following sections, we look at the various facets of surveillance systems in a more detailed and concrete manner. After a short historical sketch (Section 8.2), technical issues (Sections 8.3, 8.4, and 8.5) and then, on this basis, the most important question, namely the objectives and applications of surveillance (Section 8.6), are discussed. Finally, some examples of specific surveillance systems are presented (Section 8.7) and some useful sources for further study indicated (Section 8.8).

8.2 History

Epidemiologic surveillance of infectious diseases is relatively young. It could indeed not exist before health authorities existed to whom reports would be made, which was hardly the case before the late 18th century (Rosen 1993, Chapter 5). An exception were the reports on mortality based on death certificates, which gave rise to the first health statistics in the 17th century, due to John Graunt (Rosen 1993, Chapter 4). In order to be comparable on a wide scale they necessitated an international classification of causes of death and later of general morbidity. This was initiated at the International Statistical Congress in 1853, then continued by the International Statistical Institute, and finally taken over by the World Health Organization (WHO) in the form of the present International Classification of Diseases (ICD).

Surveillance really got started with the obligation imposed on physicians and hospitals to report cases of "notifiable" communicable diseases to health authorities. The oldest notification system is the one in England and Wales, which began with the "Infectious Disease Act" of 1889.

Surveillance in the sense of the general definition stated at the beginning evolved only after World War II. The definition given by Langmuir (1963) and affirmed in 1968 at the 21st World Health Assembly still restricts its scope to ". . .the number of incident cases . . .." The general concept appears in a paper by the Centers for Disease Control and Prevention (1986).

While the classical system of notifications was more or less the same all over the world as far as the basic ideas are concerned, the subsequent development took different forms in different countries. The form of their health systems determined that of their surveillance systems to a large extent. In centralized state-run health systems, one attempted to build all-embracing *health information systems* that consisted of regular, for example, monthly, reports from the basic health facilities upwards through the hierarchy of district health offices and provincial health departments to the Ministry of Health. In some countries, especially in the former or presently socialist ones, these systems were, or still are, quite elaborate; in others, in particular in the developing world, they often remain fairly rudimentary. In any case, in principle, they cover almost all aspects of activities, from consultations and treatments to preventive work, health education, and administrative and

economic matters. Information on infectious diseases is just one part. Sometimes special subsystems were set up to deal with particular diseases such as tuberculosis, malaria, or AIDS; see, for example, the system in Vietnam (Section 8.7, below).

In comparison, surveillance in countries that have decentralized and mainly private health systems is usually organized in a much less systematic and comprehensive way. It consists of different parts constructed ad hoc for specific purposes.

8.3 Sources of Information

The main primary sources of data and of indicators are the following:

1. Persons and households.
2. Schools, workplaces, and similar institutions.
3. Population registers.
4. Death certificates.
5. Health facility records.
6. Health insurance records.
7. Laboratory records.
8. "Sentinel" records.
9. Monitoring reservoirs and evolution of vectors.

Let us elaborate a bit; examples are given in Section 8.7.

The first type of source, persons and households, is mostly exploited in special surveys and studies. Surveillance systems based directly on them are indeed rare because people cannot be expected to regularly file reports about their health situation to any authority. The only possible surveillance is the so-called active one (Section 8.5). In such a surveillance system, health officials pay routine visits to the sources in question in order to collect the information.

Schools, homes for the elderly, restaurants, factories, and other institutions are subject to epidemiologic surveillance in many countries. Again, in most cases, only active surveillance can work.

Population registers belong to routine demographic information systems that exist in some form in most countries. For example, in Europe, these systems often arose from registers of births, marriages, and deaths that were first kept by parishes. Nowadays birth and death registrations are almost universally integrated into the general civil administration.

Death certificates are ideally written by a physician and then forwarded either to a health administration or to the general civil administration or both. They normally contain information about the main, and sometimes about secondary, causes of death classified according to ICD-10 codes.

Health facility records are the main source of information. On the level of primary health care, there are, depending on the structure of the health system, patient records of the general practitioner or registers of consultations in a health station, in

a polyclinic, or in the outpatient ward of a hospital. On the secondary and tertiary level, we have a multitude of documentations in hospitals. There are, for example, the classical books of entry and exit (discharge) of patients. Each ward has case registers, and often the hospital keeps a central, or master, index of patients. In industrialized countries, most hospitals routinely use centralized electronic hospital information systems, which integrate data from all of these sources.

Patient-based surveillance may also be restricted to a particular group of persons, for example, pregnant women or drug addicts.

Laboratories are, next to case notification and case reporting from health facilities, the most important source of information for infectious disease surveillance. They may be part of a polyclinic or a hospital, or independent. The normal independent laboratory serves the general practitioners and small clinics in its neighbourhood. In addition there are reference laboratories for special tasks on a national, regional, or global scale such as the various WHO reference laboratories. By their very nature, laboratories are obliged to keep precise records that are mostly case- or patient(person-) based.

A *sentinel* is an institution set up for the purpose of observing, recording, and reporting health-related information. It may be a small station, also called a surveillance site, built especially to this end. It can also be an already existing station that will be especially equipped or a single general practitioner designated for this task. Sentinels are practically always organized in the form of sentinel *networks*. Their function is to obtain needed information if getting it from the "normal" general surveillance system based on health facilities is impossible, or too expensive, or too slow. Sometimes, especially in developing countries, they function as a source for *integrated* surveillance that handles information of very varied nature and serves several purposes. Other sentinel surveillance systems may cover only a specific disease.

Instead of *fixed* sentinels, there is sometimes a scheme of taking *varying* samples from the target population. Some systems of sero-surveillance work like this (see Sections 8.5 and 8.7).

Sources of information on animal reservoirs, hosts, and vectors that may be relevant for observing and controlling infectious diseases vary very much depending on local conditions. There are many that work on a routine basis and thus enter into the realm of our definition of surveillance.

Every surveillance system is meant to monitor health-related information that concerns a certain *target population* or *target area* in which we are interested and that needs to be specified in advance, for example, all inhabitants of a given province of a certain country or a certain animal population. The question then arises whether the sources of information that we are actually using are *representative* of the entirety of existing sources in the habitual sense of statistics, i.e. up to an error that is considered acceptable. In the usual notification systems as well as in comprehensive health information systems, this is the case since *all* available sources are being taken into account, at least in theory. A sentinel system, however, is normally exploiting only a sample of sources. Hence it must include a statistical estimation of sampling errors, including those due to various biases. On the other hand, it may in

fact yield more precise information, for example, in the form of indicators, because it is less prone to measuring errors when collecting data and usually also has more material and personnel at its disposal.

8.4 Form and Content of Information

Information transmitted within a surveillance system is either in the form of *individual data* or in that of *indicators* computed from a set of data.

Individual data concern, for example, single cases of a communicable disease to be reported in a notification scheme. Case definition is an integral and fundamental part of the scheme. In general, it follows the ICD-10, but in notifications from the primary level, the available laboratory facilities do not always suffice to distinguish, for example, between amoebic and bacterial dysentery. In addition to the tentative or confirmed diagnosis we might have data like place and time of the case, personal data of the patient and his contacts, and certain risk factors. Depending on the "target" disease, other data may need to be reported, for example, in the case of rabies a bite by a suspect animal.

Data from laboratories concern, among others, the results of diagnostic tests and more details about the infective agent obtained, e.g. by molecular typing (see Chapter 7).

We distinguish between *nominative* notifications, which allow the receiver of the information to identify the patient, and *non-nominative* ones.

Side effects of curative or preventive treatments are also usually reported in the form of data concerning individual cases. Other examples of data appear in the surveillance of animal populations, a current one being that of birds having been diagnosed with avian influenza H5N1 virus infection.

In *syndromic* surveillance, taken up in the following section, the information handled concerns observed symptoms and even more distant clues to the occurrence of cases such as sales of over-the-counter medication and ambulance rides.

However, most information treated within a surveillance system has the form of indicators concerning groups of people such as incidences, prevalences, mortalities, and case fatality rates. They are mostly derived from individual case records by *aggregation* (also called account consolidation in bookkeeping). This is particularly true for comprehensive health information systems, which, however, cover only fairly basic information. When deriving incidences or prevalences from reported results of laboratory tests, the question of the sensitivity, specificity, or predictive values of the tests used comes up.

In more specialized surveillance systems we find the statistics of other features of case management, for example, *compliance* with a certain drug treatment such as the "standard" or the "short" treatment of tuberculosis (Chapter 16), with a multi-drug treatment of an HIV infection (Chapter 18), or with oral rehydration of children dehydrated by diarrhoea (Chapter 17). Drug *resistances* of pathogens

like those against antibiotics or against the current malaria treatments, and resistance of vectors against insecticides, are being reported in the form of individual or of aggregate data depending on circumstances. In *sero-surveillance*,, one deals with aggregate data on the immunity of human populations against vaccine-preventable diseases. There may also be indicators about the distribution of risk factors as in the *behavioural* (second generation) HIV surveillance (see Section 8.7).

8.5 Mechanisms of Surveillance

A surveillance system consists, in the first place, of methods for collecting information and then of procedures to transmit it to those who might analyse and use it. The analysis is sometimes already integrated into the system, at least in part. Let us look at the mechanisms for doing all of this.

Most of the relevant information is buried in some records kept at the sources listed above. The question is how to extract and transmit it. We distinguish two basic categories of methods: *passive* and *active* surveillance. In passive surveillance, information is taken from the records, sometimes processed locally by aggregation and then reported to those for whom it is meant, following established rules. The receivers, usually higher health authorities, do not intervene. This is the normal procedure in, for example, the notification of particular communicable diseases or the comprehensive health information systems mentioned in Section 8.2.

On the other hand, in active surveillance, those who are carrying it out have to collect the information by themselves. This may be done by routine telephone calls to "sentinel" practitioners as in the early European systems (Section 8.7) or by contacting clinics, hospitals, and laboratories regularly. Direct visits by health officials to health facilities also imply the many advantages of personal contacts. Another example is the active search for cases of chronic infectious diseases like tuberculosis, malaria, or leprosy, which is sometimes done systematically, especially in developing countries. Here, health workers visit households regularly, thus exploiting the source no. 1 listed in Section 8.3.

Naturally, passive surveillance requires as a rule fewer human and financial resources than does an active one, but the information transmitted is often full of gaps and marred by errors, and usually arrives slower except in very well-organized and automated systems. For ways to build efficient health information systems, see Krickeberg (2007).

One also distinguishes between *mandatory* surveillance on the one hand, also called *statutory* or *compulsory* surveillance, and *voluntary* surveillance on the other hand. In a mandatory system, the collection and transmission of information is regulated by laws and decrees. Most comprehensive health information systems as well as infectious disease notification systems are of this type.

The accessibility of data at the various sources is sometimes described by the *iceberg* metaphor. The emerging part represents the accessible information, which depends on the mechanism of surveillance. The classical iceberg phenomenon

derives from the fact that cases appear in the registers of health facilities only if the patient had a contact with the health system. Furthermore, even when the patient sought medical care, his case may not have been diagnosed or diagnosed but not reported. In order to find the "hidden" cases, active surveillance may be used, and to estimate the "under water" prevalence, a sample survey in the population is needed. The immune status of populations is not monitored within the standard health facility-based surveillance and requires additional sero-surveillance.

When describing and distinguishing surveillance systems, the time dimension must also be taken into account. In *concurrent* surveillance, data is collected, recorded, and transmitted at the moment it originates or very shortly afterwards. The notification of certain communicable diseases falls into this category and more generally any surveillance that requires urgent action. Most surveillance is *retrospective*, although not over long time spans, by exploiting, for example, registers of consultations only weekly or monthly.

The means of *transmitting* information is part of the mechanisms of a surveillance system. Here, anything imaginable has been used. A voluntary health worker in a developing country may make regular oral reports to his communal health station. Mail is of course widely employed, but reports may be handed over as well at the occasion of routine meetings of health officials. Active surveillance is largely based on personal visits to the sources by those collecting data. The telephone is still an important tool whereas e-mail and Internet have replaced telegraph and telex.

As a second step in the surveillance mechanism, after the collection of indicators from the sources and some initial handling and transmission, so-called *health reporting systems* were organized recently in many places and on many levels, either locally, nationally, regionally (e.g. European), or globally (WHO). They take the information from existing basic systems, arrange it further, process it in a coherent fashion, analyse it, store it in the form of databases, and publish it in view of the various objectives to be enumerated in the following section. An example in the United States described by Pascual et al. (2003) is the reporting system on tetanus, which uses the Centers for Disease Control and Prevention (CDC) notification system as its basis. More common are reporting systems that concern several diseases, in fact both infectious and non-infectious ones, founded on various bases. The description of the system of the WHO (WHO Data and Statistics 2008) lists many national systems in addition. For Europe, see Europa – Public Health-Health Information (2008).

By "spatial surveillance", one refers to a system where data and indicators include geographical information, for example, about a case, an incidence, or a finding of a pathogen, and where spatial analysis is essential in the evaluation; see Chapter 10 and the book by Lawson and Kleinman (2005). Similarly, if both the location and the time of every registered case are recorded and if this data is entered into the analysis, one speaks of "spatio-temporal surveillance".

Fairly recently, the term "syndromic surveillance" has entered the arena to designate one more scheme for reporting and analysing data from health facilities. It is, in fact, both very old and very new. It is old because often, especially in developing countries, diagnoses are recorded and reported that base themselves exclusively

on some clinical symptoms, i.e. on a clinical syndrome. Incidences are computed and published on this base. Such a syndromic surveillance ought to include correction methods in order to derive estimates of the "true" incidences as opposed to the reported ones (Krickeberg 1994). New syndromic surveillance is more related to outbreak investigation and is to some extent motivated by the fear of terrorist attacks by pathogenic micro-organisms. The objective here is to identify the nature of cases rapidly on the basis of reported syndromes and other observations (Lawson and Kleinman 2005).

8.6 Objectives of Surveillance

The objectives of epidemiologic surveillance of infectious diseases were sketched in a general way at the end of Section 8.1. Let us scrutinize them now in a more concrete fashion.

The purpose of notifications of specific communicable diseases is to elicit rapid intervention. Such interventions may be the isolation of infected persons and perhaps of their contacts, or quarantine of entire groups of people, or preventive vaccinations. Smallpox has been a notifiable disease from the beginning and it was by rapidly vaccinating everybody around a diseased person (ring vaccination) that it was finally eradicated (Fenner 1988).

The classical active surveillance, or screening, of school children, for example, by a tuberculin test or for caries (which is in principle an infectious disease!) aimed in the first place at early treatment, but also at obtaining epidemiologic knowledge and at containing, for example, the spread of tuberculosis.

As mentioned before, outbreak investigation of epidemics may make use of routine surveillance too; its objectives will be treated in the following chapter.

In the last 50 years or so, many more objectives were added to these classical ones. In the first place, beyond the old statistics of causes of death, the indicators on general morbidity obtained via comprehensive or partial health information systems allow health officials to monitor the distribution and extent of infectious diseases across geographical areas and population groups, and their evolution in time. This, in turn, is an important component of the basis for managing the health system, for example, for drawing up yearly budgets. It also gives rise to publications like annual Health Yearbooks that provide a general picture of the health situation of a region or a country. It is indispensable for planning particular health strategies on the one hand and the structure of the health system on the other. Finally, it may help to evaluate measures for preventing and controlling infectious diseases.

Regarding demographic surveillance, its main traditional objective has been to calculate *rates.* Indicators like total number of new cases during a given period, or of existing cases at a given moment, are converted into incidence or prevalence rates by dividing them by the respective number of inhabitants.

In the recent past, other types of surveillance systems appeared in response to the need for information of a different nature. In sero-surveillance, the degree of

immunity of the target population is monitored in order to complement the normal disease surveillance, to plan and to evaluate vaccination strategies, and to serve as a basis for mathematical modelling. Analogous objectives have led to surveillance systems of the type sketched at the end of Section 8.4, such as surveillance of compliance and behaviour of patients, of general changes in the health behaviour of the population, of changes in other risk factors, of new drug resistances and secondary effects, of resistance of pathogens and vectors, and of appearance of new forms of pathogens. The objective is always to continuously adapt the health strategies being used to newly observed situations. In addition, the results of surveillance give rise to epidemiologic and biomedical studies and insights concerning, for example, the aetiology of specific diseases and other causal relations, their pathways and seasonal or long-term trends, various risk factors including social ones, and other characteristics (for further details, see Chapter 4, 7, and 14).

For every surveillance system the question naturally arises as to what extent it attains its objectives, in other words, the issue of its *evaluation*. Given the multitude of objectives, it is not possible to enter into details here; see Centers for Disease Control (2001) and Chapter 3 of the book by Lawson and Kleinman (2005). The general ideas and statistical methods are similar to those of the evaluation of a clinical test as expressed by the concepts of *sensitivity, specificity*, and *predictive values:* Which fraction of the existing cases is being reported by the system and what is the extent of underreporting? How many affirmative reports about cases are unfounded? What can we infer from reported incidences, prevalences, or mortalities about the true ones?

8.7 Some Examples of Specific Surveillance Systems

Notification Systems. We are going to have a look at the mandatory notification system in England and Wales, mentioned in Section 8.2 (McCormick 1993), because it is the oldest one. In the present system, cases from a list of 30 diseases are to be reported immediately by the attending physician to a local health authority. The reports are nominative. The local health authorities forward this information weekly in a non-nominative way to the Health Protection Agency in Colindale, North London. The list comprises the following diseases including case definitions: acute encephalitis; anthrax; cholera; diphtheria; dysentery; enteric fever; food poisoning; leprosy; leptospirosis; malaria; measles; mumps; rubella; meningitis (meningo- and pneumococcal); viral meningococcal septicaemia (without meningitis); haemophilus influenzae; ophthalmia neonatorum; paratyphoid fever; plague; poliomyelitis; relapsing fever; scarlet fever; smallpox; tetanus; typhus; tuberculosis; viral haemorrhagic fever; viral hepatitis (types A, B and C); pertussis; yellow fever. They are categorized according to different levels of "urgency."

The systems in most other countries are basically similar. Another example would be in the United States CDC's National Notifiable Disease Surveillance

System (2008). However, in this system, only the notification to state health authorities is mandatory, whereas the notification by the states to CDC is voluntary and governed by state legislation.

General "comprehensive" health information systems. They are defined in Section 8.2. Lippeveld et al. (2000) presented their typical structure and the problems from which they suffer. Krickeberg (1999) described the example of the entirety of the health information systems in Vietnam.

Surveillance of particular infectious diseases. For certain diseases, special surveillance systems outside the general notification scheme have been developed. Some are sentinel systems as in the examples mentioned below. Others are run by a specialized central institution, for example, by a malaria or tuberculosis institute in a developing country (Krickeberg 1999). They rely on passive reporting along hierarchical paths from commune over district and province level to the central institute in question; hence their structure is usually similar to that of a general health information system. Depending on the country, they may actually or in theory be integrated into it, or be independent. A more recent example is the Tuberculosis–Leprosy Management System in Malaysia sketched in Section 6.5.

Looking at developed countries, Norway has had a central Tuberculosis Registry organized similarly to a Cancer Registry since 1962; see Norwegian Institute of Public Health (2008). It also keeps a central Registry of Vaccinations.

As illustrated in Section 8.5 by the reporting system for tetanus in the United States (Pascual et al. 2003), for many notifiable diseases there exist a specific *reporting system* for transmitting, analysing, and exploiting the information on the notified cases.

Health information systems for "vertical" programmes. These are programmes in developing countries organized "top-down" such as CDD (Control of Diarrhoeal Diseases), ARI (Acute Respiratory Infections), HIV/AIDS, MCH (Mother and Child Health), and EPI (Expanded Programme on Immunization). Every one of them uses an information system, which is implemented and operated by the organization that runs the programme, for example, a central health institute, the UNICEF, or a non-governmental organization. In general it is independent of the general health information system of the country from which it borrows, however, the hierarchical structure. Its objectives are planning and evaluating the programme and, above all, its management. Naturally, there is a strong *surveillance* component. For examples, see Krickeberg (1999). The large number of these information systems, together with those described before, frequently leads to "over-surveillance", which becomes a heavy burden on the health system and its personnel (Krickeberg 1999, Lippeveld et al. 2000).

Surveillance in schools, work places. Surveillance systems that take their sources in schools (as sketched in Section 8.6) are old and widespread but are usually limited to a few diseases. In some European countries, more comprehensive syndromic surveillance systems have been set up recently.

Surveillance in places of work is part of occupational hygiene and very varied, depending on the type of work and the social structure of the country in

question. Surveillance in restaurants, cafeterias, etc. is performed within the administrative structures of food control and also takes very many forms. Hence we will not present particular examples. Its role in outbreak investigations is described in Chapter 9.

Sentinel stations. The "International Network of field sites with continuous Demographic Evaluation of Populations and Their Health in developing countries" (INDEPTH ; 2002) counts fixed stations in many countries. They have a fairly wide area of responsibilities as indicated by their name, where surveillance of trends of the situation of infectious diseases and their risk factors plays a prominent role.

In many European countries a fixed sample of general practitioners is selected for surveillance of specific infectious diseases. Reporting was originally done by telephone and is now done by Internet or e-mail; see, for example, Weinberg et al. (1997). The British system described by Hawker et al. (2005) comprises about 70 physicians. Other examples are the European Influenza Surveillance Scheme (2008) and the European Network on Imported Infectious Disease Surveillance (2009) (see Section 21.2.1).

Surveillance of nosocomial infections. An example is given in Chapter 22.

Sero-surveillance. This is, in the first place, the surveillance of the immune status of the population for infectious diseases, mostly vaccine-preventable ones, which lead to sero-conversion of infected individuals. It started in several countries with single sample surveys that are evolving over time into a surveillance system by being repeated in a more or less systematic fashion. There exist two basically different sampling methods. In the system in England and Wales (Osborne et al. 2000) and the one in Australia modelled after it, sera samples that had been submitted for diagnostic testing and would otherwise have been discarded are used. In the United States (Gergen et al. 1995) and the Netherlands (de Melker 1998), population-based random sampling is employed. The former method is of course much cheaper, which enabled those systems to advance more towards regular surveillance, for example, in Australia by a yearly survey in specific age groups and one across the entire age range every 5 years. On the other hand, population-based random sampling makes it possible to include certain additional risk factors and is less prone to bias (see also Chapter 14).

Another type of sero-surveillance singles out particular risk groups as its target populations. For example, potential blood donors are being examined for HIV or HCV.

The European Sero-Epidemiology Network (ESEN) (Osborne et al. 1997) was established in 1996 mainly in order to standardize sero-surveillance in its member states. ESEN also serves as the framework of ad hoc surveys, for example, about pertussis toxin antibodies between the years 1994 and 1998 and their relation to historical surveillance and vaccine programme data (Pebody et al. 2005).

Vector surveillance. Hosts of rabies such as foxes, stray dogs, bats, and wildlife have been subject to surveillance for a long time. For the present, see WHO Expert Consultation on Rabies 2004 (2005). National health administrations often do some surveillance of rats as hosts of fleas that might be vectors of *Yersinia*

pestis by requiring reports from beer and food factories, large restaurants, and the like.

Surveillance of mosquitoes that carry malaria, yellow fever, or dengue is usually integrated into the reporting network of the institution entrusted with general control of the disease in question; see "Surveillance of particular infectious diseases". There are various schemes for catching mosquitoes (sampling plans) and for examining their status of infection.

Surveillance of pathogens. For an example from hospitals, see Chapter 22 on nosocomial infections (microbiologic tools are described in Chapter 7).

The example of the surveillance of *Chlamydia trachomatis* in Sweden (Söderblom et al. 2006) illustrates several general aspects. Infections by this pathogen belong to the 60 notifiable diseases in Sweden. In the late 2005 and early 2006, an unexpected fall by about 25% of the reported incidence of sexually transmitted cases was noticed in the county of Halland. It then turned out that there indeed existed cases that could not be detected by the standard laboratory test (AR) used for diagnosis. An investigation in all of Sweden followed. A *Chlamydia* genetic variant was identified where the genomic target region of the test AR had suffered a deletion and which therefore did not respond to that test. This variant can, however, still be discovered by another test (BD), which uses a different target region. Thus, constant monitoring of the tests is necessary. Moreover, the basic issue of an "evolution driven by diagnostic methods" comes up since a genetic variant that is not detected and treated may spread more easily than others. See also Chapter 20 for the epidemiology of *Chlamydia* infections.

Pathogen surveillance for some vaccine-preventable infections such as those caused by meningococci C, pneumococci, or human papillomaviruses serves to detect strain replacement, shifts in strain composition, and virulence factors. It is also important for monitoring antibiotic and antiviral resistance. For details, see the relevant WHO documentation.

Surveillance of efficacy and side effects of curative and preventive treatments. This belongs to the domain of therapeutic trials including those of immunizations and other preventive treatments. Surveillance has the form of post-marketing surveillance (phase IV trials) of drugs and surveillance of vaccination efficacy and side effects after the implementation of an immunization programme. It is a huge area apart; hence no example will be given here (see, however, Chapter 14).

Second-generation surveillance. This concept stems from the surveillance of AIDS and its pathogen HIV. There, systems using different sources and mechanisms, dealing with various types of information, and pursuing several objectives were advocated and tried out. Second-generation surveillance now means building efficient systems that combine the two basic forms of AIDS/HIV surveillance. One of them is usually called *biological* surveillance and deals with the distribution of cases over risk groups and geographical areas, and with the occurrence of opportunistic infections, CD4 counts, viral loads, and the like. Data on other sexually transmittable diseases may be included. *Behavioural* surveillance concerns general risk factors (see Chapter 18), behaviour in the strict sense being the most prominent

one. The mechanisms may be based either on sentinels, mostly clinics and hospitals, or on multiple rounds of population-based sample surveys. For details, see Rehle et al. (2004) and Reintjes and Wiessing (2007).

Spatial surveillance. This had been defined at the end of Section 8.5. Chapter 10 presents some examples. The book by Lawson and Kleinman (2005) describes several more, in particular in its Chapter 7.

Syndromic surveillance. The System of the New York City Department of Health and Mental Hygiene (Heffernan et al. 2004) which started in 2001 uses daily electronic reports on certain syndromes from consultations in emergency departments of hospitals in order to spot outbreaks as early as possible. Not surprisingly, most respiratory and fever type syndromes occur during peak influenza activity, and diarrhoeal and vomiting syndromes are mainly observed during periods of suspected norovirus and rotavirus transmission. For other examples see Lawson and Kleinman (2005).

8.8 A Guide to Further Study

Many books on epidemiology or public health contain a chapter on surveillance, most of it concerning infectious diseases, for example American Public Health Association (2000), Hawker et al. (2005), Nelson and Masters Williams (2007), Thomas and Weber (2001), Webber (2005), and Rothman and Greenland (1998).

The volumes edited by Teutsch and Churchill (2000) and Reintjes and Klein (2007) provide a general, practical overview on surveillance. Statistical methods are treated in Brookmeyer and Stroup (2004) on an intermediate level; there is also a long list of selected sources of information. The book by Lawson and Kleinman (2005), although in principle restricted to spatial and syndromic surveillance, touches in fact upon most issues of modern surveillance in developed countries and emphasizes the mathematical and statistical techniques. On a less technical level, Nsubuga et al. (2006) deal with surveillance in developing countries.

References

American Public Health Association (2000) Control of communicable diseases manual. American Public Health Association, Washington, DC

Brookmeyer, R and Stroup, D, eds. (2004) Monitoring the health of populations: Statistical principles and methods for public health. Oxford University Press, Oxford

CDC's National Notifiable Disease Surveillance System (2008) www.cdc.gov/ncphi/diss/nndss (accessed 29 February 2008)

Centers for Disease Control (1986) Comprehensive plan for epidemiologic surveillance. Centers for Disease Control, Atlanta, Georgia

Centers for Disease Control (2001) Updated guidelines for evaluating public health surveillance systems: Recommendations from the Guidelines Working Group. MMWR 50 (13), 1–35

de Melker HE, Conyn-Van Spaendonck MA (1998) Immunosurveillance and the evaluation of national immunization programmes: A population-based approach. Epidemiol Infect 121, 637–643

Europa – Public Health-Health Information (2008) http://ec.europa.eu/health/ph_information/information_en.htm (accessed 24 February 2008)
European Influenza Surveillance Scheme (2008) www.eiss.org (accessed 10 January 2008)
European Network on Imported Infectious Disease Surveillance (2009) www.tropnet.eu (accessed 7 April 2009)
Fenner F (1988) Smallpox and its eradication (History of International Public Health, No. 6). World Health Organization, Geneva
Gergen PJ, McQuillan GM, Kiely M, Ezzati-Rice TM, Sutter RW and Virella G (1995) A population based serologic survey of immunity to tetanus in the United States. New Engl J Med 332, 761–766
Hawker J, Begg N, Blair I, Reintjes R and Weinberg J (2005) Communicable disease control handbook, 2nd ed., Blackwell Science, Oxford
Heffernan R, Mostashari F, Das D, Karpati A, Kulldorf M and Weiss D (2004) Syndromic surveillance in public health practice, New York City. Emerging Infect Dis 10, 858–864
INDEPTH (2002) INDEPTH, health and demography in developing countries, vol. 1: Population, health and survival at INDEPTH sites. IDRC, Ottawa
Krickeberg K (1994) Health information in developing countries. Frontiers in Mathematical Biology. Lecture Notes in Biomathematics 100, 550–568
Krickeberg K (1999) The health information system in Vietnam in 1999. Assignment report for the joint programme of Vietnam and the European Committee on Health Systems Development. Available from the author on request
Krickeberg K (2007) Principles of health information systems in developing countries. Health Inf Manag J 36 (3), 8–20
Langmuir AD (1963) The surveillance of communicable diseases of national importance. N Engl J Med 268, 182–192
Lawson AB and KleinmannK, eds. (2005) Spatial and syndromic surveillance for public health. Wiley, Chichester
Lippeveld Th, Sauerborn R and Bodart C, eds. (2000) Design and implementation of health information systems. World Health Organization, Geneva
McCormick A (1993) The notification of infectious diseases in England and Wales. Commun Dis Rep CDR Rev 3, 19–25
Nelson KE and Masters Williams CF (2007) Infectious disease epidemiology: Theory and practice. Jones and Bartlett, Sudbury
Norwegian Institute of Public Health (2008) www.fhi.no (accessed 28 January 2008)
Nsubuga P et al. (2006) Public health surveillance: A tool for targeting and monitoring interventions. Chapter 53, in: Jamison, DT et al. Disease control priorities in developing countries. Oxford University Press, New York
Osborne K, Weinberg J and Miller E (1997) The European sero-epidemiology network. Euro Surveill 2, 29–31
Osborne K, Gay N, Hesketh L, Morgan-Capner P and Miller E (2000) Ten years of serological surveillance in England and Wales: Methods, results, implications and action. Int J Epidemiol 29, 362–368
Pascual FB, McGinley EL, Zanardi L., Cortese MM, Murphy TV (2003) Tetanus surveillance – United States, 1998–2000. MMWR CDC Surveill Summ 52 (3), 1–8
Pebody RG et al. (2005) The seroepidemiology of *Bordetella pertussis* infection in Western Europe. Epidemiol Infect 133, 159–171
Rehle Th, Lazzari S, Dallabetta G and Asamoah-Odei E (2004) Second-generation HIV-surveillance: better data for decision making. Bulletin WHO 82, 121–127
Reintjes R and Klein S, eds. (2007) Gesundheitsberichterstattung und Surveillance: Messen, Entscheiden, Handeln. Verlag Hans Huber, Bern
Reintjes R and Wiessing LG (2007) 2nd-generation HIV surveillance and injecting drug use: uncovering the epidemiological surveillance ice-berg. Internat J Public Health 52, 166–172

Rosen G (1993) A history of public health. Expanded Edition. John Hopkins Press, Baltimore
Rothman KJ, Greenland S and Lash TL, eds. (2008) Modern Epidemiology. 3rd ed. Philadelphia: Lippincott Williams and Wilkins
Söderblom T, Blaxhult A, Fredlund H and Herrmann B (2006) Impact of a genetic variant of Chlamydia trachomatis on national detection rates in Sweden. Euro Surveill 11 (12) E0612071
Teutsch SM and Churchill RE, eds. (2000) Principles and practice of public health surveillance. 2nd ed. Oxford University Press, New York
Thomas JC and Weber DJ, eds. (2001) Epidemiologic methods for the study of infectious diseases. Oxford University Press, Oxford
Webber R (2005) Communicable disease epidemiology and control: A global perspective. 2nd ed. CABI Publishing, Oxfordshire
Weinberg J, Nohynek H and Giesecke J (1997) Development of a European electronic network on communicable diseases: the IDA-HSSCD programme. Euro Surveill 2 (7), 51–53
WHO Data and Statistics (2008) www.who.int/research/en (accessed 3 March 2008)
WHO Expert Consultation on Rabies 2004 (2005) WHO Technical Report Series 931. WHO, Geneva