The basis of classification is the species. Often it is necessary, especially in epidemiology, to subdivide a species into vare (synonym types). Cultures of a species that have certain characteristics in common are grouped together. Examples are biovar, phagovar, pathovar, morphovar, and serovar.

The term strain is used in different ways. In clinical bacteriology, it refers to the initial culture of a species isolated from a patient during an infection. In epidemiology, isolates of the same species from different patients are also referred to as belonging to the same epidemic strain.

It is important to know that there is no official, internationally valid classification of bacteria. Therefore, especially the higher taxa are often grouped according to practical aspects. For example, a classification based on the practical needs of medicine can be used, e.g. the classification used in the standard work "*Bergey's Manual of Systematic Bacteriology*" [27, 28].

1.5.2 Nomenclature

Nomenclature as the second subfield of taxonomy comprises the naming of the taxonomic groups. The "*International Code for the Nomenclature of Bacteria*" defines the rules for naming. Accordingly, a species is identified by two Latinized names: the first name characterizing the genus and the second the species. Families are designated with the suffix "-aceae." In contrast to the classification, names accepted by the "*International Committee of Systematic Bacteriology*" are considered official and binding.

1.6 Medical Microbiology

Some microorganisms can cause infectious diseases (see Table 1.7). Infection or contagion is the transmission, adherence, and invasion of microorganisms into a macroorganism such as humans, animals, or plants [29]. The site where the infectious agent resides is called the primary source of infection. Secondary sources of infection are objects or third persons involved in indirect transmission.

1.6.1 Infection Routes

Humans have several entry points for potential pathogens. The route of infection can be direct or indirect.

1.6.1.1 Direct Routes

- Fecal–oral (smear infection): Salmonella, Shigella, Vibriones, EHEC, and hepatitis A virus.
- Aerogenic (droplet infection): Mycobacterium *tuberculosis, Bacillus anthracis* (pulmonary anthrax), *Legionella pneumophila* (Pontiac fever), *Coxiella burnetii* (Q fever), *Francisella tularensis* (tularemia, rabbit plague), and *Chlamydia psittaci*.

Table 1.7 Infectious diseases and their modes of transmission, pathogens (causative agents), and infectious doses.

Disease	Incubation period	Initiating agent/infectious dose	Transmission
Tuberculosis	4–6 weeks	*Mycobacterium tuberculosis* 1 cell (guinea pig model)	Aerogenic (oral)
Legionellosis	2–10 days	1 cell of *Legionella pneumophila* in respirable aerosol droplets.	Aerogenic
Mite spotted fever	?	3 cells of *Orientia tsutsugamushi*	Bite
Q Fever	14–21 days	10 cells of *Coxiella burnetii*	Aerogenic
Tularemia	4 days	10 cells of *Francisella tularensis*	Aerogenic
Rubella	12–21 days	≥10 Rubella virus (portal of entry pharynx). 60 Rubella virus (entry nasal mucosa)	Aerogenic
Trichinosis	5–10 days	50–70 *Trichinella spiralis*	Oral
Syphilis	14–28 days	60 cells of *Treponema pallidum*	Mucosa
EHEC infection	2–10 days	10–100 enterohaemorrhagic *Escherichia coli*	Oral
Flu	1–3 days	340 influenza viruses	Aerogenic
Shigellose/Ruhr	2–7 days	10–200 cells of *Shigella flexneri* 10^9 cells of *Shigella dysenteriae*	Oral
Campylobacter	3–5 days	500 *Campylobacter jejuni*	Oral
Enteritis	2 weeks	10^3 *Giardia lamblia*	Oral
Pulmonary anthrax	1–7 days	≥1300 cells of *Bacillus anthracis*	aerogenic
Typhoid	12–14 days	10^5 cells of *Salmonella typhi*	Oral
Cholera	1–2 days	$>10^6$ *Vibrio cholerae*	Oral
Food poisoning	4–6 hours 1–3 days	(a) *Bacillus cereus*: oral 10^5–10^6 Bacilli/g food. b) *Clostridium botulinum*: lethal dose: 0.1–1 µg toxin A	Oral
Diarrhea	Hours	10^8 enterotoxigenic *Escherichia coli (ETEC)*	Oral
BSE, scrapie	Years	$>10^5$ infectious prions PrP^{sc}	Oral
Fever	After 20 minutes	Endotoxins of Gram−negative bacteria 1 ng = 0.1 EU from 5 EU/kg body weight fever reaction	Intravenously Intrathecal

- Genital (sexual intercourse): *Treponema pallidum,* Candida (thrush), HIV, and hepatitis B and D viruses.
- Cutaneous: staphylococci and dermatophytes.
- Pränatal: intrauterine infection of the fruit, infection routes via the placenta or from the fallopian tubes, infection after rupture of the membranes, with the abbreviation Toxoplasmosis, other, Rubella, Cytomegaly and Herpes (TORCH) the most important diseases are named: Toxoplasmosis (*Toxoplasma gondii*),

other (such as syphilis, listeriosis), Rubella (viruses), Cytomegaly (viruses), and Herpes simplex (viruses).
- Perinatal: hepatitis B, C, and D viruses; in premature infants, nosocomial infections due to Streptococcus, Klebsiella, and Listeria; umbilical wound infections; conjunctivitis due to chlamydia.
- Inoculation (through puncture wounds and cuts, animal bites, and stings): Rhabdoviruses (rabies), HIV, and hepatitis B viruses via infected needles; Rickettsia, Borrelia, TBE viruses, and Plasmodia via insect bites.

1.6.1.2 Indirect Route

Through

- Water: *Vibrio cholerae*.
- Food: *Bacillus cereus, Staphylococcus aureus,* Enterobacteriaceae, and *Clostridium perfringens*.
- Dust/soil: *Bacillus anthracis* and *Clostridium tetani*.
- Contaminated items: catheter infections (*Staphylococcus epidermidis*).
- Vectors: vectors are for example Ixodes ricinus, TBE viruses, Borrelia and others.
- The human (hand contacts): touching pus and blood.
- Medical/medical measures (iatrogenic): nonsterile instruments.

In sepsis (septicemia), microorganisms enter the bloodstream. The blood distributes them to the various organs so that foci of inflammation then form there. Typical sepsis pathogens are *Staphylococcus aureus, Streptococcus pyogenes, E. coli, Klebsiella pneumoniae, Pseudomonas aeruginosa*, and *Bacteroides fragilis* (an obligate anaerobic intestinal bacterium). Each year, more than 150 000 people in Germany develop sepsis, with nearly 50% dying as a result [30].

1.6.1.3 Nosocomial Diseases

The Section 2 of IfSG defines the term nosocomial infection as "an infection with local or systemic signs of infection as a reaction to the presence of pathogens or their toxins, which is temporally related to an inpatient or an outpatient medical procedure, as long as the infection did not already exist beforehand."

Nosocomial diseases can affect hospitalized patients (Greek: nosokomeion for hospital) by facultative pathogenic bacteria such as *Pseudomonas aeruginosa* and a number of other Gram-negative water bacteria (so-called "wet germs") as well as skin and mucous membrane germs (Staphylococcus and Streptococcus), yeasts such as *Candida albicans*, enteropathogenic fecal germs, and viruses (cytomegalovirus, coxsackievirus, ECHO virus, etc.) [31]. The source of infection is either the patient himself/herself or other patients, visitors, or medical staff. Nosocomial infections can be controlled by a strict hygiene regimen.

1.6.1.4 Zoonoses

Zoonoses are diseases of humans, with animals serving as sources of infection (see Table 1.8). In rare cases, the animal may infect the human, and then the human in turn may infect the animal, e.g. cat scratch disease; the causative agent is the

Table 1.8 Some human diseases and the probable animal sources of infection.

Animal source of infection	Disease	Pathogen
Fox, dog, and cat	Echinococcosis	*Echinococcus multilocularis*
Domestic cats and animals for slaughter	Toxoplasmosis	*Toxoplasma gondii*
Pork, beef, poultry, and eggs	Salmonellosis	*Salmonella enterica*
Rats (rat flea)	Pest	*Yersinia pestis*
Herbivorous animals (e.g. sheep and cows)	Anthrax	*Bacillus anthracis*
Chimpanzees	AIDS	HI virus
Great apes	Hepatitis B	HB virus
Cattle, sheep, and goats	EHEC infection, HUS	EHEC
Dogs, wolves, foxes, and bats	Rabies	Rhabdovirus
Bats	Ebola	Ebola virus
Bats and flying foxes	Hemorrhagic fever	Marburg virus
African monkeys	Yellow fever	Flavivirus
Wild and domesticated mammals	Chagas disease	*Trypanosoma cruzi*
Wild birds	Influenza A	Influenza viruses
Ticks	Lyme disease	*Borrelia burgdorferi*
Creeping cat (Viverridae)	SARS	Coronavirus

Source: References [9, 32, 33].

Gram-negative bacterium *Afipia felis*. Currently, approximately 800 zoonotic infectious diseases are known; among them, toxoplasmosis is the most common zoonosis [32]. Pet zoonoses include parrot disease, toxoplasmosis, echinococcosis, canine roundworm infection, and skin rashes caused by fungi transmitted from guinea pigs, rabbits, hamsters, mice, dogs, and cats. Hygiene measures such as daily cleaning of cages and toilets and thorough hand washing after animal contact, as well as regular worming and vaccination of pets, protect against infection. At least two new, unknown zoonoses are found in humans every year.

Substances of animal origin are used in the manufacture of drugs and medical devices, e.g. lactose, skim milk powder, and calcium lactate (from bovine milk); magnesium stearate (from animal fats); and gelatin (from bones, hides, and tendons). These examples are *excipients*. Active ingredients are derived from slaughterhouse materials such as porcine intestinal mucosa (heparin), pancreas (pancreatin or purified enzymes such as lipases, colipases, amylases, and proteases), gastric mucosa (pepsin), blood (hemin and albumin), liver (liver extract), thymus, bile (fel tauri, glycocholic acid, cholates, and deoxycholates), testes (hyaluronidase), and other organs (various organ extracts). These starting materials must be free of pathogenic microorganisms, viruses, and infectious prions, or the manufacturing process must include safe depletion or inactivation steps. This also applies to

pharmaceutical products manufactured from human material (e.g. clotting factors, immunoglobulins and albumin from blood, extracts, and enzymes from organs). Virus-depleting procedures include filtrations such as nanofiltration and chromatographic methods; inactivation procedures include irradiation with UV-C light (100-200 nm), precipitation, treatments with acid (e.g. 60 minutes at pH 3), and exposure to dry heat.

The three pillars of virus safety are as follows:

- Donor screening.
- Sufficient capacity for virus depletion/inactivation during the manufacturing process.
- Validated manufacturing process.

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