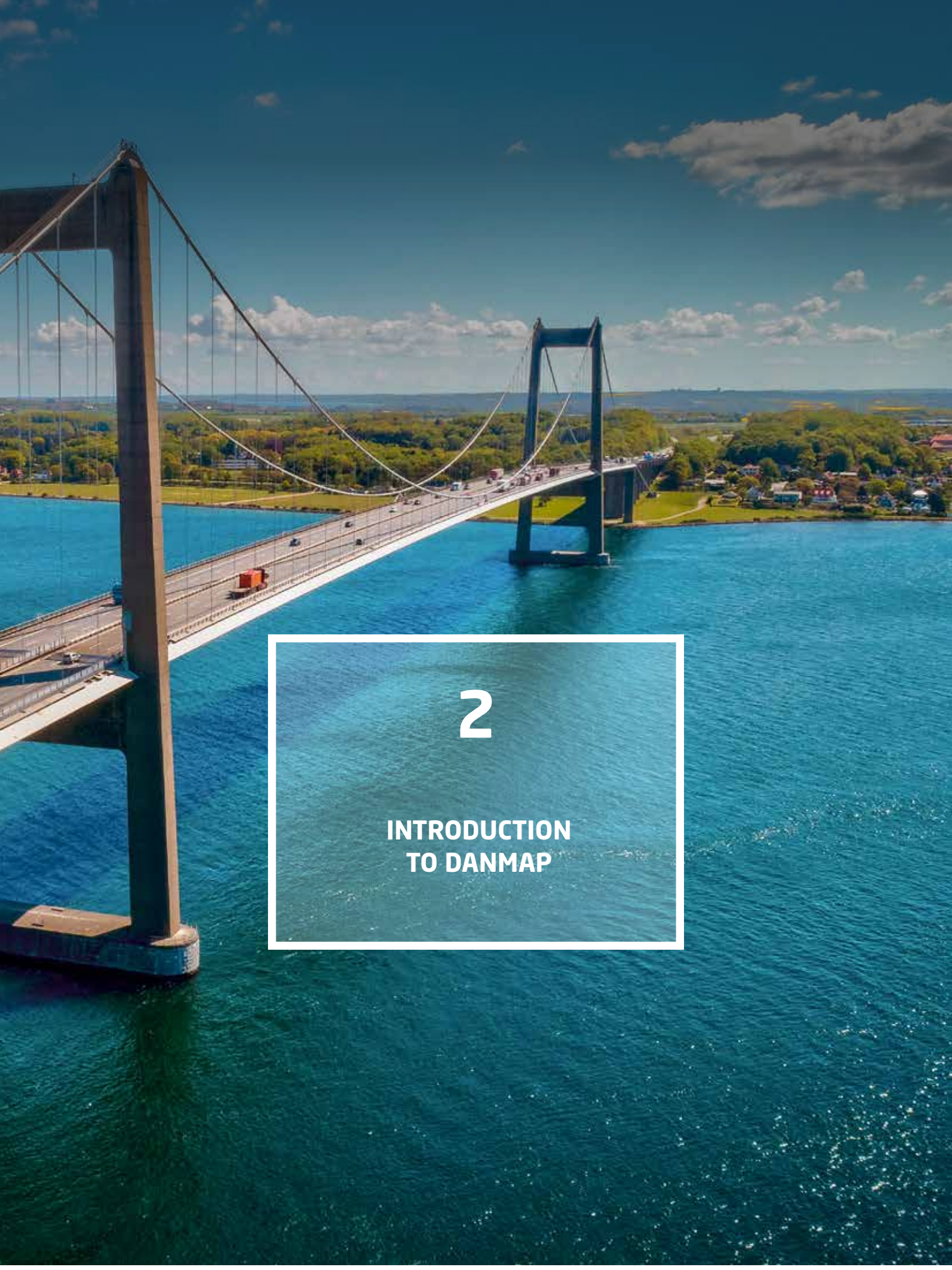


2

INTRODUCTION TO DANMAP

2. Introduction to DANMAP

2.1 The DANMAP surveillance system

DANMAP is a surveillance system with five key objectives:

- To establish the state-of-nation in regards to the use of antimicrobial agents in food-producing animals and humans
- To carry out surveillance of the occurrence of antimicrobial resistance in bacteria isolated from food-producing animals, food of animal origin (meat) and humans
- To identify areas for further research, e.g. antimicrobial resistance transmission or possible associations between antimicrobial consumption and antimicrobial resistance
- To deliver data to veterinarians, medical doctors and other health professionals for the development of antibiotic treatment guidelines
- To act as a knowledge base for authorities, academia and politicians when performing risk assessment and management, thus supporting decision making in the prevention and control of resistant bacterial infections

Since 2021, DANMAP also provides an integrated analysis of resistance in bacteria from humans and food animals.

The monitoring programme was initially developed in 1995 by researchers, based on frequent discussions and exchange of knowledge and results from research. Since then, DANMAP has evolved into a governmentally supported programme.

However, much of the design of the programme, including participation of the human laboratories and referral of strains is based on a voluntary principle.

DANMAP surveillance relies on four equally important components: well-established and well-functioning diagnostic systems, well-designed and representative surveys, reliable registers as well as mutual trust and openness between all collaborators.

A positive effect of the regular meetings and exchange between stakeholders is that these prove helpful in other aspects, for example, by contributing to a common knowledge pool regarding laboratory methods. This ensures and contributes to continuous improvements and harmonisation of the laboratory work. Meetings across sectors and between different stakeholders also contribute to a better mutual understanding, facilitating development and work towards mutual goals.

Surveillance is a complex undertaking and DANMAP encompasses many different surveillance components and covers resistance in different populations and contexts.

These categories of bacteria are included in DANMAP:

- Human clinical isolates to reflect the antimicrobial resistance levels in the human population that seeks medical care
- Foodborne zoonotic bacteria along the whole farm-to-patient chain to monitor the levels of antimicrobial resistance in shared pathogens
- Indicator bacteria from healthy food-producing animals to monitor status of antimicrobial resistance in the animal reservoirs
- Clinical isolates from sick food-producing animals to monitor resistance

The National Food Institute at the Technical University of Denmark (DTU) and the National AMR reference laboratory at Statens Serum Institut (SSI) are responsible for data interpretation and output communication mainly via the annual DANMAP report and seminar. Interpretations are independent of policy, risk management and private industries.

The DANMAP programme is funded jointly by the Ministry of Health and the Ministry of Food, Agriculture and Fisheries. Support from the ministries has also helped build the databases and maintaining the registers, which the current surveillance system relies upon.

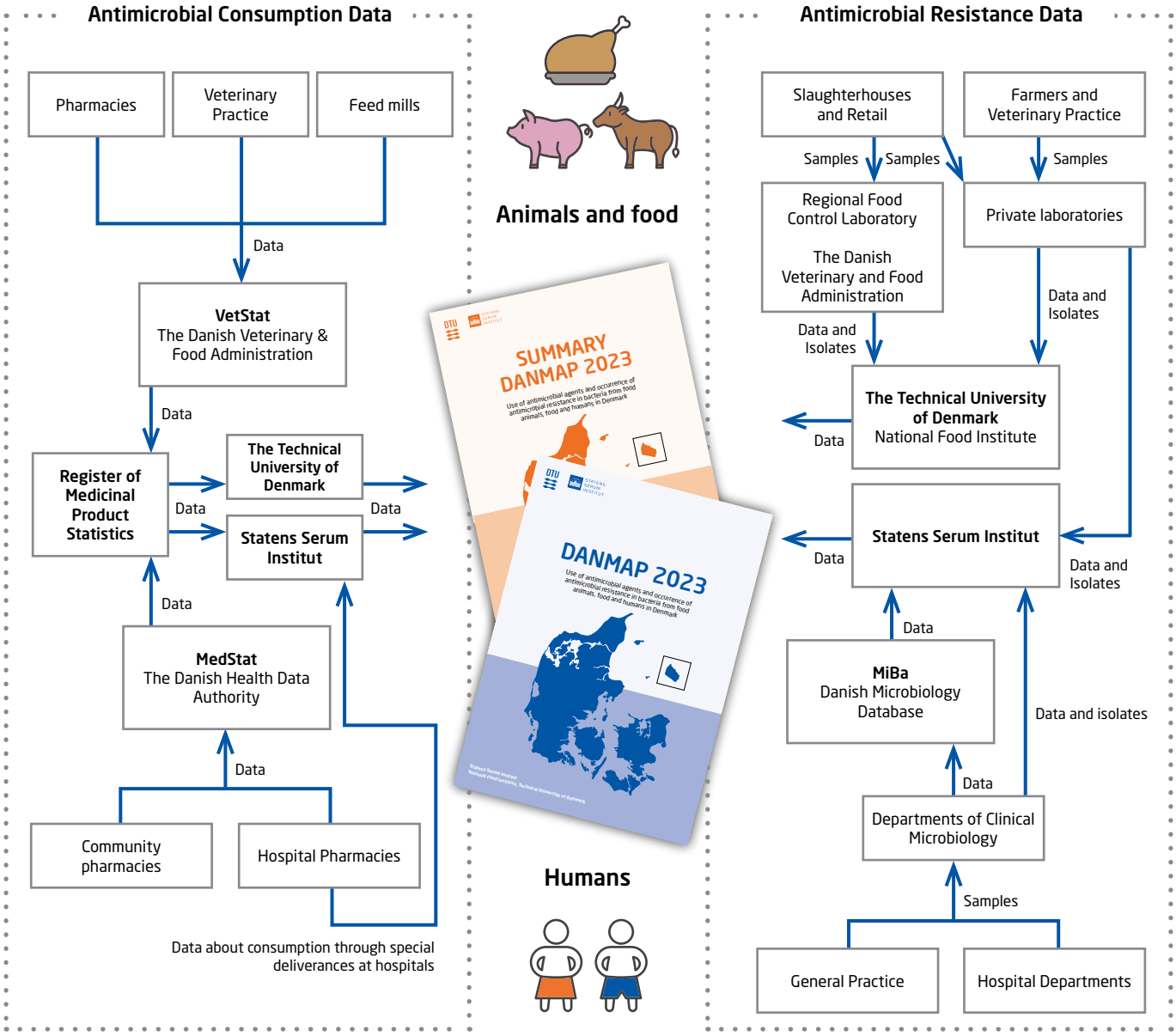
For further information on the development and history of DANMAP, please read Chapter 2, "DANMAP – A 20 year perspective" in DANMAP 2015 and Chapter 1, "DANMAP - the beginning" in DANMAP 2020.

Organisation and data flow

Since 1995, a main purpose of DANMAP has been to monitor the entire chain from farm to fork to patient. The organisation and collection of DANMAP data and the interdisciplinary collaboration between sectors and organisations is presented in Figure 2.1.

The introduction of whole genome sequencing (WGS) has been a big step forward for surveillance purposes and in outbreak situations and has become routine standard in many clinical laboratories and most reference laboratories. However, phenotypical testing is still considered relevant, more feasible, cheaper and sometimes faster, especially in a clinical setting. Phenotypical testing also continues to be used in combination with WGS to describe and determine which resistance genes are relevant to look for when using molecular analysis. Furthermore, it complies with EU regulations in food and animal testing.

Figure 2.1 Organisation DANMAP regarding data and data flow DANMAP 2023



Bacterial isolates from food, food animals and humans are submitted to the Regional Food Control Laboratory or occasionally the Technical University of Denmark and Statens Serum Institut, respectively, for further phenotypic and genotypic characterisation (Figure 2.1). The choice of the methods in surveying different bacteria and infections is described in more detail in the different chapters and sections of the report.

Figure 2.2 The five Danish healthcare regions and their respective population distributions. In addition, the ten DCMs are marked by black dots. The grey dot indicates the national reference laboratories (NRL) situated at Statens Serum Institut DANMAP 2023

North Denmark Region

No. of inhabitants	594,634
No. of inhabitants/km^2	75
No. of inhabitants/GP	1,780

Central Denmark Region

No. of inhabitants	1,358,879
No. of inhabitants/km^2	104
No. of inhabitants/GP	1,655

Capital Region of Denmark

No. of inhabitants	1,891,871
No. of inhabitants/km^2	738
No. of inhabitants/GP	1,721

Region Zealand

No. of inhabitants	849,857
No. of inhabitants/km^2	118
No. of inhabitants/GP	1,918

Region of Southern Denmark

No. of inhabitants	1,237,413
No. of inhabitants/km^2	101
No. of inhabitants/GP	1,543

GP = General Practioner
DCM = Department of Clinical Microbiology
NRL = National Reference Laboratories

Data source: Statistics Denmark [www.dst.dk] and the Danish Medical Association [www.laeger.dk]

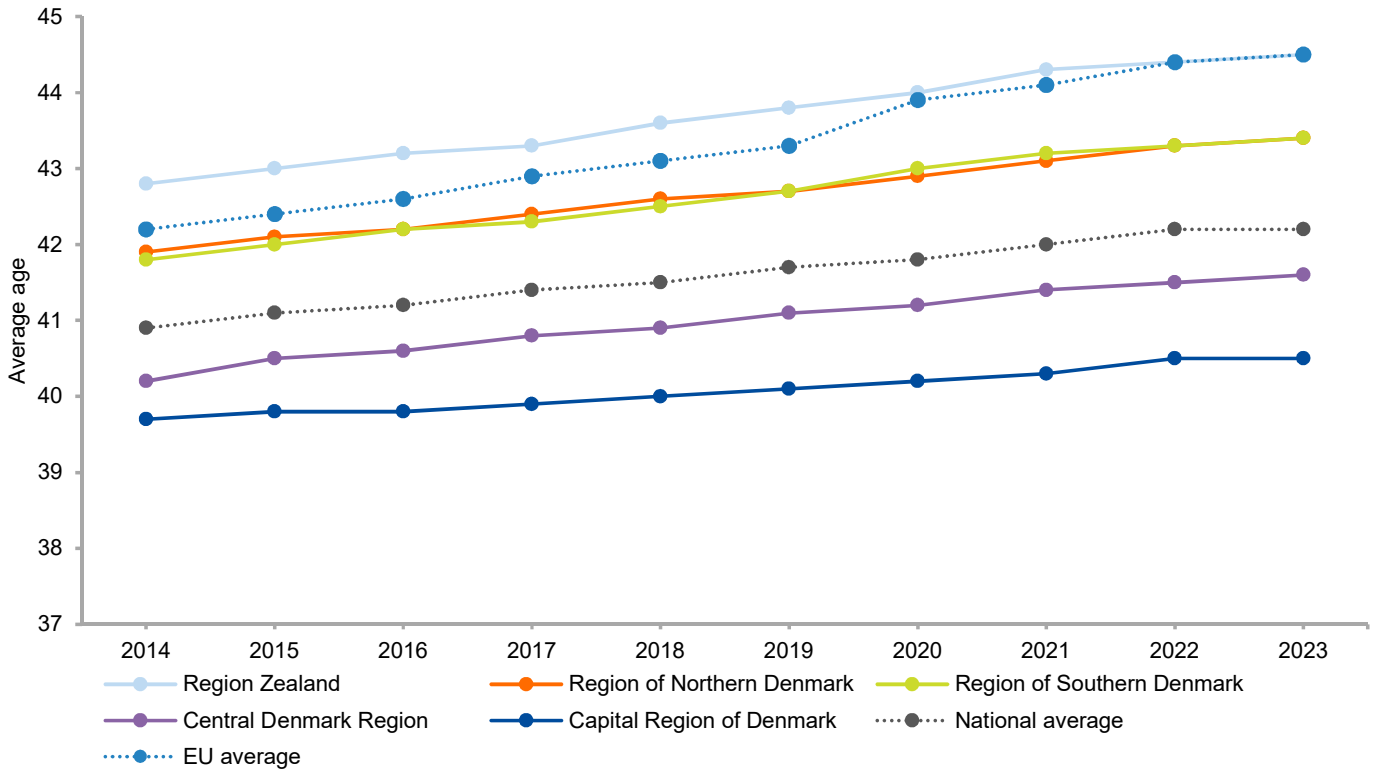
2.2 Information on demographics and health care system

During the past 27 years, the human population in Denmark has increased from approximately 5.2 million inhabitants in 1995 to 5.9 million in 2023 [www.dst.dk]. Simultaneously, the average age has increased gradually. In 2023, the national average age was 42,2 years. The population and the respective regional distribution, in 2023, is presented in Figure 2.2, while regional differences and changes in age are presented in Figure 2.3.

In Denmark, microbiological analyses are carried out by ten hospital departments of clinical microbiology (DCMs) situated at the main regional hospitals, Figure 2.2. The analyses performed cover all samples from public hospitals and most samples from general practitioners (GPs). In addition, some GPs perform culturing of urinary samples from their patients. In the Capital Region of Denmark one private laboratory also performs additional analyses for the GPs.

Data on regional and national health care activity at hospitals in 2014 and 2023 are presented in Table 2.1. Denmark has a very high bed occupancy rate at hospitals and can reach maximum capacity during winter time for example due to high influenza activity. In 2023, the number of admissions at Danish somatic hospitals was registered to be 693.169 and the number of bed-days was registered to be 2,911,257. From 2014-2023, the number of bed-days decreased by 26%, the number of admissions decreased by 11% whereas the Danish population grew by 5%.

Figure 2.3 Changes in average age, Denmark and EU, 2014-2023 DANMAP 2023



Data source: Statistics Denmark and Eurostat

Table 2.1 Activity at Danish hospitals, 2014 and 2023 DANMAP 2023

Region	Number of bed-days in somatic hospitals		Number of admission to somatic hospitals		Population	
	2014	2023	2014	2023	2014	2023
Capital Region of Denmark	1,594,168	948,225	273,023	229,441	1,749,405	1,891,871
Region Zealand	504,223	443,558	105,106	102,149	816,726	849,857
Region of Southern Denmark	755,226	587,570	162,134	142,407	1,202,509	1,237,413
Central Denmark Region	726,610	602,411	168,010	147,794	1,277,538	1,358,879
North Denmark Region	370,362	329,494	73,370	71,378	581,057	594,634
Denmark	3,950,589	2,911,257	781,643	693,169	5,627,235	5,932,654

Data: Activity at somatic hospitals
Data source: The National Patient Register

2.3 Information on animal population and food production system

Denmark is an agricultural country, with more than half of its area managed by the agricultural sector. Livestock is of great importance and approximately 25% of the agricultural enterprises are specialised in the production of livestock, mainly pigs, cattle and chicken. The agricultural sector contributes around 24% of the Danish export earnings [Danish Agriculture and Food Council, 2019].

The production of food-producing animals as well as the production of meat and milk are presented in Table 2.2 and 2.3.

2.4 Registered antimicrobial agents

Table 2.4 shows the antimicrobial agents registered to treat bacterial infections in humans and animals. Some of these are listed on the highest priority list of medically important antimicrobials for the treatment of bacterial infections in humans, according to definitions made by the World Health Organization [WHO 2024]. In order to be considered critically important or highest priority critically important an antimicrobial class or subclass with authorized use in humans and animals must meet two criteria; 1) be the only - or one of a limited number of compounds available to treat serious human infections and 2) be used to treat infections caused by bacteria that are either possibly transmitted from non-human sources, or carry resistance genes from non-human sources.

Furthermore, when both criteria are met, two prioritization factors are applied: 1) the antimicrobial class contains at least one antimicrobial that is both on the WHO Essential Medicines List (EML) and is classified as Watch or Reserve on the AWaRe classification list; 2) the antimicrobial class is used to treat human infections, often invasive and life-threatening, for which there is extensive evidence of transmission of resistance from non-human sources. When both prioritization factors are met, the antimicrobial is Highest Priority Critically Important (HPCIA), otherwise it is classified as Critically Important (CIA). Thus, in the newest list revision from 2024, four drug classes were considered highest priority critically important: 3rd and 4th generation cephalosporins, quinolones, polymyxins and phosphonic acid derivatives. Additionally, three antimicrobial classes were considered critically important: aminoglycosides, macrolides and ansamycins. In Denmark, the use of HPCIA classes in food-producing animals has generally been absent or reduced through either voluntary or legislative restrictions, while there is some use of the CIA classes aminoglycosides and macrolides. See Chapter 4 for more information.

Furthermore, other antimicrobials may also be restricted due to national risk mitigation. For trends and preferred therapeutic choices in the antimicrobial treatment of humans, see Chapter 5.

Growth promoters are no longer used for animals in Denmark and are shown in parentheses in Table 2.4. Most of these influenced Gram-positive bacteria. Since 1995, the indicator enterococci from animals and meat have been used to monitor resistance towards former growth promoters.

Table 2.2 Production (1,000 heads) of food animals, Denmark DANMAP 2023

	Pigs		Cattle		Poultry	
Year	Total	Exported [a]	Slaughter cattle	Dairy cows	Broilers	Turkeys [b]
2014	30002	11120	556	563	115497	595
2015	30874	12133	511	561	114238	598
2016	31660	13280	540	572	120685	834
2017	31662	14173	509	570	117602	601
2018	32571	14449	533	575	122268	642
2019	31694	14897	518	567	123976	661
2020	32018	14736	500	567	120508	684
2021	32646	14092	506	564	118431	467
2022	31669	13856	493	557	114698	427
2023	29353	14865	486	..[c]	123803	358

Source: Statistics Denmark. Export data for poultry from Statistics Denmark, personal communication until 2022 and from www.dst.dk in 2023
a) Export of live pigs. These are included in total number of heads
b) Since 2006, more than 99% of the turkeys have been exported for slaughter
c) .. indicates that the observation is missing, discretionary or too uncertain to state

Table 2.3 Production (mill kg) of meat, milk and fish, Denmark DANMAP 2023

						Farmed fish [c]	
Year	Pork	Beef	Broiler meat [a]	Turkey meat	Milk [b]	Land based	Marine net ponds
2014	1944	143	174	9	5592	32	14
2015	1954	135	172	9	5744	36	16
2016	1943	142	182	10	5892	36	12
2017	1896	135	178	7	6088	37	14
2018	1967	142	185	10	6305	38	14
2019	1864	137	187	8	6323	41	14
2020	1952	133	195	8	6394	36	11
2021	2079	134	144	6	6390	37	12
2022	1956	128	200	6	6392	32	14
2023	1663	126	207	6	6377	-	-

Source: Statistics Denmark. Export data for poultry from Statistics Denmark, personal communication until 2022 and from www.dst.dk in 2023
a) Average weight after slaughter for poultry from Statistics Denmark, personal communication until 2022. In 2022, a final slaughtered weight of 1.74 kg per broiler produced and 12.93 kg per turkey produced was estimated. The same weight estimates were used in 2023
b) Conventional and organic
c) The numbers for 2023 are not final. Data are based on accounts statistics for aquaculture. The production of farmed fish includes fish transferred from one production facility to another

Table 2.4 Antimicrobial agents registered for systemic and veterinary intramammary therapeutic use in animals and humans, Denmark DANMAP 2023

ATC / ATCvet codes [a]	Therapeutic group	Antimicrobial agents within the therapeutic groups	
		Animals	Humans
J01AA / QJ01AA,QJ51AA	Tetracyclines	Chlortetracycline, doxycycline, oxytetracycline	Doxycycline, lymecycline, tetracycline, tigecycline, eravacyclin
QJ01BA	Amphenicols	Florfenicol	
J01CA / QJ01CA	Penicillins with extended spectrum	Ampicillin, amoxicillin,	Ampicillin, pivampicillin, amoxicillin, pivmecillinam, mecillinam, benzathin benzylpenicillin
J01CE / QJ01CE	Beta-lactamase sensitive penicillins	Benzylpenicillin, phenoxymethylpenicillin, procaine penicillin, penethamate hydroiodide, benzathin benzylpenicillin	Benzylpenicillin, phenoxymethylpenicillin
J01CF / QJ51CF / QJ51RC	Beta-lactamase resistant penicillins	Cloxacillin, nafcillin	Dicloxacillin, cloxacillin, flucloxacillin
J01CR / QJ01CR	Comb. of penicillins and beta-lactamase inhibitors	Amoxicillin/clavulanate	Amoxicillin/clavulanic acid, piperacillin/tazobactam
J01DB / QJ01DB,QJ51DB	First-generation cephalosporins	Cefalexin, cefadroxil, cefapirin	Cefalexin, cefazolin
J01DC	Second-generation cephalosporins		Cefuroxime
J01DD / QJ01DD,QJ51DD	Third-generation cephalosporins incl. comb. with beta-lactamase inhibitors	Cefoperazone, ceftiofur, cefovecin	Cefotaxime, ceftazidime, ceftriaxone, ceftazidime/avibactam
J01DE / QJ51DE / QJ01DE	Fourth-generation cephalosporins	Cefquinome	Cefepime
J01DF	Monobactams		Aztreonam
J01DH	Carbapenems		Meropenem, ertapenem, imipenem and cilastatin
J01DI	Fifth-generation cephalosporins incl. comb. with beta-lactamase inhibitors		Ceftaroline fasamil, ceftolozan/tazobactam, ceftobiprol
J01EA	Trimethoprim and derivatives		Sulfathiazole, sulfadiazine, sulfamerazine, trimethoprim
J01EB / QJ01EQ	Short-acting sulfonamides	Sulfadimidine, sulfathiazole, sulfadiazine, sulfamerazine	Sulfamethizole
J01EE / QJ01EW / QJ51RE	Comb.of sulfonamides and trimethoprim, incl. derivatives	Sulfadiazine/trimethoprim, sulfadoxine/trimethoprim, sulfatroxazole/trimethoprim, sulfadimidine/trimethoprim, sulfamethoxazole/trimethoprim	Sulfamethoxazole/trimethoprim
J01FA / QJ01FA	Macrolides	Spiramycin, tylosin, tilmicosin, tylvalosintartrat, tulathromycin, gamithromycin	Erythromycine, roxithromycine, clarithromycine, azithromycine, spectinomycin, pirlimycin
J01FF / QJ01FF / QJ51FF	Lincosamides	Clindamycin, lincomycin, spectinomycin, pirlimycin	Clindamycin
QJ01XX [b]	Streptogramins	(Virginiamycin)	Framycetin
J01GB / QJ01RA,QJ01GB, QJ01RV, QJ51RG, QJ51RC	Aminoglycosides	Streptomycin, dihydrostreptomycin, gentamicin, neomycin, apramycin, framycetin	Tobramycin, gentamicin, amikacin
J01MA / QJ01MA	Fluoroquinolones	Enrofloxacin, marbofloxacin, difloxacin, ibafloxacin, pradofloxacin, danofloxacin, orbifloxacin	Ciprofloxacin, levofloxacin, moxifloxacin
QJ01MB	Other quinolones	Oxolinic acid	
QJ01MQ [b]	Quinoxalines	(Carbadox, olaquindox)	
J01XA,A07AA / Not in ATCvet [b,c]	Glycopeptides	(Avoparcin)	Vancomycin, teicoplanin, dalbavancin
J01XB / QJ51RD [b]	Polypeptides (incl. polymyxins)	(Colistin, bacitracin)	Colistin
J01XC	Steroid antibacterials		Fusidic acid
J01XD,P01AB [c]	Imidazole derivatives		Metronidazole
J01XE	Nitrofurane derivatives		Nitrofurantoin
J01XX	Other antibacterials		Methenamine, linezolid, daptomycin, fosfomycin
QJ01XQ	Pleuromutilins	Tiamulin, valnemulin	
QP51AG04	Antiprotozoals, sulfonamides	Sulfaclozine	
Not in ATCvet [b]	Oligosaccharides	(Avilamycin)	
Not in ATCvet [b]	Flavofosfolipols	(Flavomycin)	

a) ATCvet codes start with a Q
b) Animal growth promoters used before 1999 are listed in parentheses
c) Intestinal antiinfectives (A07AA) and imidazole derivatives for protozoal diseases (P01AB) were, for the first time, included in DANMAP 2014, since their widespread use in the treatment of *Clostridium difficile* infections makes them belong to the most used antibiotics in human infections in Denmark