



Prospects and practicality of antimicrobial stewardship in animal health

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Summary

In today's world, what does antimicrobial stewardship (AMS) mean? Does it have the same meaning to people around the world and across One Health sectors? The objective of this article is to summarise the history and terminology of AMS, the 'five Rs' of AMS and key metrics and decision support tools, illustrate concepts through global case studies, identify barriers and facilitators, and propose a standardised definition of AMS in animal health. From the historical origins and uses of the word 'stewardship', the concepts of having responsibility, being accountable to someone or something, and the care of a valuable resource have been strong consistent themes. Across human and animal medicine, there are differences in the scope and content of what is considered prudent and responsible use, as well as AMS, and while these differences merit acknowledgement, they arise naturally from the different settings of medicine in these sectors. Fundamentally, the words capturing the concept of AMS are not as important as the intent and meaning they convey; the language should not be considered a barrier to action. When the scope of AMS incorporates aspects of the five Rs – responsibility, review, reduce, refine, and replace – it acknowledges that there are many aspects of AMS already in place in good animal rearing. Across the regions of the world, case studies have demonstrated highly successful and different approaches to stewardship initiatives and programmes in various economic settings. Challenges exist, but they do not prevent improvement and global expansion of AMS. Next steps to facilitate future AMS actions must address clarity and consistency in communication about AMS in

animals, including a globally accepted definition. The goal of this article is to advance the concept of practical AMS by reducing the need for antimicrobial use, and, when antimicrobial use is necessary, by responsible and prudent use informed by AMS principles and programmes. Improving and optimising animal health is a key AMS tool.

Keywords

Animals – Antimicrobial stewardship – Prudent and responsible use – Treatment guidelines – Veterinary.

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Introduction

Antimicrobial stewardship (AMS) is a term often included in national action plans to address antimicrobial resistance (AMR). But what does AMS mean? And does it have the same meaning to all people around the world and across One Health sectors? 'Stewardship' is a fairly uncommon word in everyday life that refers to the protection and preservation of something considered rare, irreplaceable and of great value. While stewardship has long applied to forests, oceans and rivers in the natural environment, or preservation of cultural norms and Indigenous knowledge, it can equally apply to antimicrobials, which are also rare, irreplaceable and highly valued. What is the relationship between AMS, treatment guidelines, and prudent and responsible use of antimicrobials in animals? And how can AMS be used to improve prudent and responsible use? Does 'prudent and responsible use' have the same meaning as AMS?

Since the early 2000s, the World Organisation for Animal Health (WOAH) has provided guidance on responsible and prudent use of antimicrobials in animals [1]. Currently, WOAH describes the objectives of responsible and prudent use of antimicrobials as follows: '1) preserve the effectiveness of antimicrobial agents used in veterinary and human medicine and their safety in animals; 2) comply with the ethical obligation and economic need to keep animals in good health; 3) [p]revent or reduce transfer of resistant microorganisms or resistance determinants within animal populations, between animals, humans, and the environment; 4) [p]rotect human health by ensuring the safety of food of animal origin with respect to residues of antimicrobial agents' [2]. 'Prudent', according to the *Oxford English Dictionary*, means 'of a person: acting with or showing forethought; having or exercising sound judgement in practical or financial affairs; circumspect, discreet, cautious; far-sighted' and 'of conduct, action, etc.: characterised by, exhibiting, or proceeding from prudence; judicious, sensible' [3]. 'Responsible' has several meanings, such as 'capable of fulfilling an obligation or duty; reliable, trustworthy, sensible' or 'being in charge of something; appointed to look after something' [4]. While there is a subtle distinction between these two words, with 'prudent' focusing more on judgement and 'responsible' focusing on duty or accountability, for communication regarding antimicrobial use (AMU), it is likely that these overlapping terms can be used synonymously, without any meaningful loss in concept. WOAH has chapters in both its *Terrestrial Animal Health Code* (Chapter 6.10.) [2] and *Aquatic Animal Health Code* (Chapter 6.2.) [5] dedicated to prudent and responsible use and has developed associated training e-modules, some with inclusions of AMS (<https://training.woah.org/course/search.php?search=antimicrobial>). However, WOAH currently does not have a definition of AMS.

In animal rearing, in some countries the use of antimicrobials is required by legislation or regulations to be under the prescription of a veterinarian, and in many (arguably most) cases, antimicrobials are administered to the animals by the owner. The decision in most of these cases to actually administer the antimicrobial rests with the owner even when veterinarians have prescribed and dispensed the antimicrobials. In other areas of the world, antimicrobials can still be purchased legally by the owner over the counter. These two situations indicate five actors in the antimicrobial value chain: i) regulators, ii) the pharmaceutical industry, iii) over-the-counter sellers of antimicrobials (e.g. agroveter shops, feed mills), iv) veterinarians and v) animal owners. In some areas of the world, the practice of animal medicine involves the use of veterinary paraprofessionals who might also have the authority to provide and administer antimicrobials. To address the urgent global issue of AMR, the importance of reducing the need for antimicrobials and, if needed, using the right drug, at the right dose, for the right length of time administered in the right way and early into the onset of disease needs to be clearly communicated to multiple actors with different responsibilities. Through providing consistent, situation-adaptable, clear messaging, AMS uptake by multiple target audiences can be facilitated.

The need to promote prudent and responsible use and AMS has reached the highest levels of political attention. In 2024, the United Nations General Assembly held a meeting on AMR, resulting in a global political declaration [6]. This declaration contained several mentions of stewardship, treatment guidelines and prudent and responsible uses of antimicrobials. The political declaration highlighted 'the importance of improving the appropriate, prudent and responsible use of antimicrobials across human, animal and plant health, through integrated delivery of policies that promote disease prevention and antimicrobial stewardship' [6]. This excerpt captures two important points: i) disease prevention and AMS were identified as separate elements, which implies that disease prevention is outside the scope of AMS; and ii) AMS was considered a means to improve prudent and responsible use.

The objective of this article is to summarise the history and terminology of AMS, the five Rs of AMS, key metrics and decision support tools; illustrate concepts through global case studies; identify barriers and facilitators; and propose a standardised definition of AMS in animal health. The overall goal is to advance the concept of practical AMS by reducing the need for AMU, and, when AMU is necessary, by responsible and prudent AMU informed by AMS principles and programmes. This article uses the broader term 'antimicrobials', inclusive of antibiotics, antivirals, antiprotozoals and antifungals, as the principles presented herein do not require the distinction of the type of antimicrobial, although most of the case studies covered focus on antibiotics. Antiseptics, disinfectants and other biocides are also relevant for selection of AMR (for example, disinfectants driving resistance in *Escherichia coli* [7]) but are not specifically addressed in this article.

What does stewardship, and in particular antimicrobial stewardship, mean?

Stewardship

According to the *Oxford English Dictionary*, the word stewardship was first used sometime between 1150 and 1500 [8]. The word originates from Middle English, with the components of the word reflecting ‘*stig*’ (house) and ‘*weard*’ (keeper or guardian) [9]. One of the original uses of the word was for a steward – a person within a noble’s household who was responsible for overseeing, managing and ensuring the well-being of the estate [9]. This brings forward the concepts of i) taking care of valuable goods and ii) being responsible for something/someone (accountability).

The pivotal Rio Declaration on Environment and Development of 1992 did not explicitly mention stewardship [10], but it embodied its core principles and sparked enduring global engagement on environmental responsibility. For example, in a recent book by Carnell and Mounsey entitled *Stewardship and the Future of the Planet: Promise and Paradox*, stewardship is described in the light of human responsibility to tend the earth [11], an idea that has been central to human cultures for thousands of years. Between the 1980s and 2020, the term stewardship was applied to many sectors/settings, such as the environmental sector with the concept of ‘land or countryside stewardship’ [12], foraging by different animal species as ‘natural area stewardship’ [13], ‘soil stewardship’ [14], ‘departmental stewardship’ in a human medical school [15], humanity’s stewardship of other living beings or living companions [16], animal welfare [17], human stewardship of animal welfare [18], ‘stewardship of the biosphere’ [19], stewardship of resources related to safeguarding the public from challenges arising through scientific progress [20], and coastal management and coral reefs [21]. ‘Ecosystem stewardship’ has been used to incorporate strategies that can be adapted in situations of uncertainty from a planetary perspective [22]; the topic of ‘planetary stewardship’ itself has also been raised [23]. Notably, in the poultry industry, stewardship related to the use of chemical (non-drug) products was raised as early as 1994 [24]. The pharmaceutical industry also used the phrase ‘product stewardship’ in 1999, referring to the importance of prudent use and improvement of animal husbandry to reduce the need for antibiotics [25]. The universal theme that emerges is that stewardship involves the preservation of valuable resources.

The English word ‘stewardship’ may not have direct equivalent counterparts across languages. However, there may be similar words, such as ones meaning ‘guardian’ (in the United Kingdom, stewardship came from an understanding of ‘guardianship’) or ‘protector’. From land and ecosystem stewardship comes the concept of a steward being a ‘custodian’ [26]. In the climate realm, the concept of a steward is of being a ‘trustee’ or ‘trusteeship’, which also imparts the notion of time – of protecting things for future generations [27].

Other languages likely contain words that denote the protection of valuable resources, including First Nations languages, such as the Māori term *kaitiakitanga*, describing guardianship, stewardship and protection of the environment (sky, sea and land) [28], other precious and irreplaceable resources.

Antimicrobial stewardship

Protecting antimicrobials as a valuable resource is not a new concept. As early as 1945, Sir Alexander Fleming in his Nobel lecture entitled 'Penicillin', while not using the term stewardship, warned of the inappropriate use of penicillin and both the development and consequences of resistance to penicillins [29]. Antimicrobials are medicines that do not belong to any individual. They are for the common good of humanity, for the animals that veterinarians look after, and for the plants/crops raised for food. The 'optimal antimicrobial use "stewardship"' concept appeared in the literature starting in 1996 [30].

Terminology for AMS should not be a barrier for action. Equivalent words in other languages should be identified and accommodated as much as possible. The chosen words are fundamentally not important, but rather the meaning is critical. However, the complex and somewhat technical language of antimicrobials and AMS brings challenges. Others have also commented on the differences in translation of AMS into other languages, including French, German and Dutch [31]. In East Africa, Swahili – the region's most widely spoken language – does not have a specific word for 'antimicrobial'. Instead, it uses the word 'dawa', meaning 'medicine', which can refer to any medication, from pain relievers to antimicrobials. This linguistic gap creates confusion when communicating about AMU and stewardship: patients may be unaware they are taking an antimicrobial rather than, say, an analgesic, and health-education messages often lack the precision needed to encourage stewardship.

To understand what AMS might mean at the global level across sectors, a brief scan of the literature was conducted to review how the Quadripartite (WOAH, the Food and Agriculture Organization of the United Nations [FAO], the World Health Organization [WHO] and the United Nations Environment Programme) defines or describes responsible/prudent use and AMS ([Table I](#)) [2,32-35]. While WOA and FAO have described many elements of AMS in their descriptions of prudent or responsible use or in general with respect to AMS, only WHO has specifically defined prudent use and AMS ([Table I](#)). Outside the global organisations, from a One Health perspective, even the word 'multidisciplinary' may have different meanings. For example, for human medicine, there is a recommendation for AMS programmes to be multidisciplinary, though limited to disciplines specific to human medicine, such as involving an infectious disease physician and a pharmacist with training in infectious diseases and possibly with the inclusion of a microbiologist [36].

As seen in [Table I](#), it is notable that AMS in humans is primarily focused on interventions for ensuring responsible and effective use, whereas for animals the descriptions are broader and include other aspects of animal rearing. This distinction appropriately reflects the difference in practical aspects of the scope of health across sectors. For veterinarians, in particular those caring for food-producing animals, clinical focus is on the health and welfare of animals from birth to slaughter, with the animal lifespan generally being much shorter than that of humans. A veterinarian's main duty is maintaining the health and welfare of animals. Veterinarians need to address animal welfare and consider the cost of diagnostic tests and treatment, and for livestock veterinarians there is an additional need to consider food security and safety [37]. In human medicine, while patient care and cost of medicine are inherent considerations, practitioners are generally only seeing sick people when they arrive at a clinic or hospital – although this varies by specialty and setting, with greater reliance on AMU for disease prevention in fields such as surgery and oncology and marked differences between community general practice (where most antibiotics are used) and hospital care (where infection prevention and control and AMS teams are often available). Veterinarians, through farm visits and seeing the rearing conditions of animals, have more opportunities to intervene prior to illness onset, as the farm environment lends itself to interventions that can successfully prevent the need for AMU. Hence, it is not unreasonable to expect differences in AMS concepts between veterinary medicine and human health. However, even across veterinary practice, there are fundamental differences between AMU practices in food-producing animals *versus* companion animals *versus* sporting/competition animals: the medicine and approaches to AMS will depend on whether the animal is reared individually (cats, dogs, horses) or more at the population level (member of a pen, flock, barn, etc.) [37].

In other words, AMS for veterinarians embraces the factors that keep animals well, in addition to prudent and responsible use of antimicrobials; for humans, in contrast, AMS fundamentally is about how best to use antimicrobials, and infection prevention and control practices are often considered separately and administered by different healthcare personnel. Regardless, the principles of AMS are the same, but livestock veterinarians have far greater opportunities to intervene – by acting on or advising about observed rearing conditions, feed sources, infection prevention and farm biosecurity – particularly when they are involved in an animal's whole of life, from conception to death; applying these principles is a fundamental veterinary obligation.

Key principles of antimicrobial stewardship: the five Rs

Lessons can be learnt from the history of antimicrobial discovery and use. In 1913, Dr Paul Ehrlich, the inventor of the first synthetic antibiotic for use in humans, gave an address to the 17th International Congress of Medicine on Chemotherapeutics and included the

principle of 'Frappet fort et frappet vite', which translates to 'Strike hard and strike quickly', recognising that treatment delay permits microbes to multiply and increases the likelihood of resistance emergence [38]. He also mentioned 'Viribus unitis', which translates to 'Unite forces', a precursor to One Health [38]. For AMS, this translates into the principles of i) infection detection and diagnosis (the notion of 'striking hard' implies that the aetiological agent has been identified and that the effective antimicrobial options are known) and ii) immediate use at iii) an effective dose.

Just over a decade later, Dr Alexander Fleming, although a dedicated microbiologist, did not appreciate the value of other disciplines in solving the problems he faced with his culture of penicillin producers – there was no chemist to investigate stability and develop an efficient extraction technique for identification of the active molecular entity. Fleming proposed that penicillin could be used topically to treat wounds [39]; he saw no role of penicillin as a systemic antibiotic. The critical breakthrough came from pathologist Dr Howard Florey and his colleagues in Oxford, who developed methods for large-scale extraction and purification and went on to demonstrate penicillin's systemic efficacy through extensive trials in patients with severe infections [39]. Two additional lessons can be learnt here: i) multidisciplinary teams solve more problems, and ii) grand visions lead to grand solutions.

These principles are reflected in select contemporary AMS initiatives, such as the following regional case. The chicken meat industry in Australia has an Antimicrobial Stewardship Framework [40]. The main focus of this framework is about planning how to avoid the need to use antimicrobials (implementing infection prevention and control strategies), and if antimicrobials are needed, then 'as little as possible, as much as necessary' is a guiding principle [40]. Between the actions taken at the poultry industry level and regulation of antimicrobials for sale for use in animals in Australia (e.g. fluoroquinolones are not licensed for use in food animals in Australia), Australia has very low antimicrobial sales compared to other countries [41] and very low levels of resistance in indicator and zoonotic bacteria in chicken [40,42].

These principles are encapsulated as the '5Rs' of AMS: responsibility, review, reduce, refine and replace [40,43-45]. How these principles are administered during actual antimicrobial therapy is reflected in a diagram by Lloyd and Page [45], reproduced with modifications in [Figure 1](#).

Responsibility

Effective AMS requires leadership. AMS must be seen as an overriding priority and responsibility for all those with influence on animal management and AMU. This may include regulators, corporate entities, pharmaceutical companies, veterinary practice directors,

farm owners and managers, and food-producing businesses. For Veterinary Services, who uses antimicrobials and how they are used must be made clear. Provided that a country requires a prescription for AMU in animals, the veterinarian should be accountable for deciding when to use antimicrobials and which to use, while the livestock producer should be responsible for correctly following the veterinarian's instructions and making any necessary changes to animal management practices [40]. The veterinarian needs to recognise that AMU has impacts not just on the outcome of animal, but also on resistance, which can have effects on other animals on the farm, now and in the future, as well as beyond the animal (i.e. on human health and the environment) [43]. The veterinarian also has a responsibility to leave the animal owner with a clear understanding and instructions to facilitate compliance with the prescription [43].

In WOA's *Terrestrial Animal Health Code*, Chapter 6.10., 'Responsible and Prudent Use of Antimicrobial Agents in Veterinary Medicine', responsibility is also assigned to the competent authorities (e.g. regulation of antimicrobials for sale, biosecurity and animal health plans, pharmaco-surveillance), the pharmaceutical industry (e.g. research, advertising), animal feed manufacturers (e.g. labelling, prevention of contamination, disposal) and antimicrobial distributors (e.g. labelling and keeping records), essentially encompassing all actors along the antimicrobial value chain [2]. These same principles and actors were also included in the Codex Code of Practice to Minimize and Contain Foodborne AMR [46].

Review

Both how antimicrobials are used and overall stewardship activities should be regularly reviewed [8]. Two types of review are needed. First, bacteria are constantly evolving, and historical practices may no longer work; thus, review of the effective dose, duration and route of administration is required. Measuring the overall quantity of antimicrobials used requires record-keeping and aspects of the more traditional concepts of AMU/sales surveillance [40]. However, determining the effective dose and duration requires a much more detailed examination of use practices, which involves a review of whether the right antimicrobial was chosen for the disease (indication).

Second, administering antimicrobials to animals involves human behaviour; compliance with AMS guidelines requires continuous evaluation and improvement if needed [40]. Measuring compliance and adherence to biosecurity and treatment guidelines is much more difficult than measuring the quantity used and generally requires that treatment and prescription guidelines exist for comparison [40]. On-farm or on-site audits/inspections have been proposed as being highly important to achieve AMS goals [47]. In human medicine, in some cases the audit and feedback are under national regulation. For example, in Portugal, regulations require AMS

teams in hospitals to provide audit and feedback on use of carbapenem and quinolone (and other antimicrobials) within 72 hours [48].

Reduce – keeping animals healthy

Keeping animals healthy to reduce the need for antimicrobials is an overriding and key directive of AMS. Deciding when not to administer antimicrobials (e.g. to treat any condition not caused by pathogenic bacteria, including a purely viral disease) contributes greatly to the conservation of antimicrobials [37]. Infection prevention and control through good biosecurity, nutrition and animal welfare are core elements of keeping animals healthy [40]. From a One Health perspective, the language here also needs to be clear. To many, biosecurity means more than the concepts of infection prevention and control, as in animals there is also emphasis on optimising animal disease resilience (e.g. nutrition, genetics), environmental controls and animal welfare ([Fig. 2](#)). The role of biosecurity is being more widely embraced within AMS. As stated by Corbera *et al.* in 2025, 'Effective antimicrobial stewardship (AMS) is inseparable from biosecurity' [49].

Regarding biosecurity, recently Dr Jeroen Dewulf, an expert on biosecurity in relation to AMU, defined biosecurity as '[t]he application of a set of management, behavioural and physical measures designed to reduce the risk of introduction, establishment and spread of pathogenic agents to, within and from an animal population' [50]. The European Food Safety Authority (EFSA) and the European Medicines Agency (EMA) in their Joint Scientific Opinion on Measures to Reduce the Need to Use Antimicrobial Agents in Animal Husbandry in the European Union, and the Resulting Impacts on Food Safety (RONAFA) describe biosecurity as a combination of two concepts [51]. First, they noted that it encompasses 'a set of preventive measures designed to reduce the risk of transmission of diseases in crops and livestock, quarantined pests, invasive alien species, and living modified organisms' [51,52]. Second they drew from Regulation (EU) 2016/429 [53] to include biosecurity as an aggregate single concept as 'the sum of management and physical measures designed to reduce the risk of the introduction, development and spread of diseases to, from and within an animal population or an establishment zone, compartment, means of transport, premises or location' [51].

Biosecurity can be considered to have three different components [51]: i) external biosecurity or primary prevention (bioexclusion/preventing disease introduction onto the farm – e.g. pest control, isolating new farm animals), ii) internal biosecurity or secondary prevention (biocontainment/preventing on-farm disease transmission – e.g. stocking density, early diagnosis of disease, washing boots and coveralls) and iii) tertiary prevention (individual animal resilience – e.g. vaccination, nutrition, genetic selection of animals) [40,50,51].

Logically, each of these three components involves different activities and investments and has a different magnitude of effect.

A recent scoping review of farm biosecurity studies from 2001 to 2022 found that 70.3% of studies demonstrated a positive association between biosecurity or improved management and reduced AMU [54], which in turn can decrease AMR. Using a quasi-experimental approach, a study of pig farms in Belgium found that the benefits of improving biosecurity were more than just reduced AMU, as there were also decreased mortality and increased profits (even after accounting for the costs related to improved biosecurity) [55]. A similar study conducted in Bangladesh reported comparable findings, with higher biosecurity scores associated with lower AMU – akin to observations in Malawi – underscoring the applicability and advantages of biosecurity improvements in reducing AMU across countries with differing economic contexts [56,57].

Contrary to what appears to be a prevalent belief, biosecurity does not need to be expensive, though this can depend on whether it is primary, secondary or tertiary. Primary or external biosecurity improvements, such as changing the physical structure of a barn to isolate new animal introductions, can be expensive, but secondary/internal biosecurity, such as washing hands, changing boots or washing coveralls, might not be [50].

Guardabassi *et al.* [58] include reducing overall use as one of the elements for optimising AMU in veterinary medicine (their other three elements are considered under ‘Refine’ below). The rationale is that any use of antimicrobials can select for AMR [59]. Guardabassi *et al.* [58] further note that selection for AMR is exacerbated by practices such as use when not needed, excessive reliance on broad-spectrum antimicrobials, administration of subtherapeutic doses and inappropriate treatment durations. From an AMR perspective, excessively long treatment durations are more concerning; short durations are less commonly associated with AMR risk. Too short a duration of treatment might lead to treatment failure, but less likely to AMR [60], unless resistance genes are present prior to treatment.

Refine

Refine or refinement encompasses ‘the right drug, at the right time, at the right dose, for the right duration by the right route of delivery’ [45]. The concepts are captured under the headings of infection detection, diagnosis, antimicrobial selection and optimal dosing regimen. However, putting this into practice can be very challenging: veterinarians need to stay abreast of this information for every disease condition in all the animal species under their care, taking into consideration both clinical effectiveness and AMR local profiles [58], in addition to public health and environmental considerations. Guardabassi *et al.* [58] explain this clearly and practically: ‘Thus, while it is easy to agree that antimicrobials should be used rationally, actually doing so

can be a challenge, even to the most motivated veterinarians' [58]. Additionally, there is a lack of data in the evidence base informed by robust and valid randomised controlled trials in veterinary medicine for many infectious disease treatments.

Diagnosis

Returning to Ehrlich's concept of striking quickly, disease detection and diagnosis need to be done early on, prior to the spread of the disease within an individual animal and throughout the farm in the case of livestock management. Human health research has indicated that early implementation of antimicrobials in the course of disease is a highly important factor for preventing the selection of AMR [61]. Similarly, an experimental study of calves infected with *Mannheimia haemolytica* showed the benefits and effectiveness of early administration of the antimicrobial under study, targeting a lower bacterial load [62]. More disease leads to increased potential AMU and elevated selection pressure for AMR. To accomplish early intervention, livestock producers and veterinarians need cost-effective tools that enable rapid detection and diagnosis and accurate decision-making (such as point-of-care tests and laboratory testing; more details are provided under 'Decision support tools to support antimicrobial stewardship'). Such tests are generally not available or accessible on the market [58]. Constructing accurate case definitions that are refined and validated through diagnostics and training is also necessary in this aspect of AMS [58].

Antimicrobial drug selection

When the decision is made to use an antimicrobial for treatment, prevention or control, this should balance the risks of AMR in addition to the benefits that the medication provides [40]. As AMR is a One Health issue, the risks and benefits considered should include those to the animals, humans and the environment, while recognising the challenge that this poses for veterinary practitioners. For human health, the WHO AWaRe classification (antimicrobials are classified as Access, Watch and Reserve) can be used as a high-level guide for appropriate AMU in the absence of local guidelines [63]. However, no such global classification exists for animals at the time of writing. EMA has created a categorisation of antimicrobials for use in animals, with the purpose of protecting human health, that has categories of A–D for Avoid, Restrict, Caution and Prudence [64], and similarly, WHO has a List of Medically Important Antimicrobials [65].

In terms of other globally accessible resources, WOAHA has created technical reference documents for several animal species/groups (bovines, dogs and cats, aquatic species, poultry and swine) that list the antimicrobials considered to be important in those species from an access perspective, although WOAHA specifically states that these reference documents are not intended to be treatment guidelines [66]. The International Society for Companion

Animal Infectious Diseases has published guidelines for antimicrobial use for treatment of respiratory and urinary tract diseases in cats and dogs, and skin diseases in dogs [67-70]. There has also been a recent systematic review of antimicrobials for acute diarrhoea in dogs by the European Network for Optimization of Veterinary Antimicrobial Treatment [71]. The respiratory guidelines emphasise that the recommendations should be interpreted as 'reasonable and appropriate for the majority of cases', while acknowledging that there are regional differences in availability of antimicrobials, AMR and restrictions on antimicrobials [67]. Finally, the World Veterinary Association (WVA) and WOAH in 2018 created a repository of antimicrobial treatment guidelines, and while the individual guidelines are not formally endorsed by WVA or WOAH, the repository is a highly valuable collection of useful information for which the organisers are actively seeking updates [71].

If local or regional disease-specific guidelines exist for the animal species, they should be consulted, and narrow-spectrum antimicrobials should be preferentially chosen over broad spectrum antimicrobials, wherever appropriate and possible. Broad-spectrum antimicrobials may exert a wider impact on the commensal microbiota and hence contribute more significantly to the selection of AMR [58].

Optimal dosing regimen

In addition to timing of initiation of antimicrobial therapy, the optimal dosing regimen includes route, dose, dosing interval and duration [58]. It has also been recognised that labelled doses and dosing regimens were/are originally developed to ensure the products work as intended for the disease indication (efficacy), not to prevent AMR [45]. Optimal dosing regimen should also consider potential impacts on commensal organisms [72].

One note about recent use of 'appropriate' and 'inappropriate' use: AMU requires good data on indication, dose, duration, route of administration, and use of guidelines and diagnostic tools [37], recognising that these elements cannot be captured by surveillance of import or sales data but require information at the veterinary, pharmacy or farm level. Record-keeping is critical, as details on the dosing regimen, indication and result are essential for the review of antimicrobial success/effectiveness. Treatment failures need to be explored to understand why and to take corrective action should the disease situation be experienced again. Records enable the veterinarian to evaluate their prescribing practices.

Route of administration

Optimal AMU ideally has minimal effect on the commensal microbiota of the gastrointestinal tract, which are also affected by antimicrobial selection pressure [58]. In animals, the largest biomass of bacteria can be found in the large intestine, where commensals, animal pathogens

and zoonotic pathogens can co-exist [58]. Even parenteral administration of antimicrobials often results in concentrations in the gastrointestinal tract that are sufficient to select for resistance [73]. In fact, the majority of antimicrobials available in veterinary medicine are excreted via the digestive tract, principally because of low bioavailability [73], with abundant bacterial flora (both resistant and susceptible) and with active drug metabolites subsequently excreted into the environment. Despite these challenges, the oral route of administration is often the easiest, most feasible and most cost-effective approach for administering antimicrobials to animals. New drug development for systemic administration should consider improvements to bioavailability and inactivation in the gastrointestinal tract [58]. If appropriate to the disease condition, topical and targeted therapies should be considered over systemic administration [45].

Dose

Dosing has many factors that need to be taken into consideration – bioavailability, time-concentration pharmacokinetics profile, minimum inhibitory concentration of the pathogen, protein binding and likelihood of target attainment [58] – adding to the complexity of decision-making for veterinarians. Changing the dose according to the minimum inhibitory concentration may be a way of improving AMS in the future, although there are tissue residue and food safety consequences, and more work needs to be done in this area [58]. With respect to pharmacokinetics, the disease state of an animal can alter plasma clearance rates: diseased animals may have longer clearance times [58,74]. However, particularly in the situation of metaphylaxis (and perioperative prophylaxis), generally only a single appropriately timed dose is recommended for administration [58]. Research in this field is also needed to inform AMS activities.

Dosing interval and duration

Duration of antimicrobial administration requires a fine balance: it must be long enough that the animal's immune response can eliminate the infection, without risking more opportunities for resistance selection [58] (especially when resistance genes are already present). Lessons that can be learnt from human medicine include selecting the shortest duration possible (only as long as needed) [36], as several researchers have critically reassessed conventional treatment durations and repeatedly found that shorter is better [75-77].

Replace

If a product needs to be administered, does it need to be an antimicrobial? There is a distinction between products that can keep animals healthy (also encompassed by the overlapping 'R' of 'Reduce') *versus* products that can actually replace the therapeutic activity

of an antimicrobial. These two concepts are often combined into the heading of ‘alternatives’, although they are very distinct in how they work from a stewardship perspective.

Antimicrobial replacements need to be effective and also should not ideally select for AMR. In other words, anything that is an antimicrobial will be exerting some selection of the bugs that can survive [40]. Alternatives can include the following: antibodies, antimicrobial peptides, bacteriophages, clays (including zeolites), competitive exclusion products, enzymes, essential oils, immunomodulators, minerals, organic acids, phytochemicals (chemicals obtained from plants), predatory bacteria, prebiotics, probiotics, postbiotics and synbiotics [51]. However, in a review of the literature, EFSA and EMA concluded that very few studies could demonstrate that alternatives positively affected animal health parameters [51]. Key challenges remain for alternatives, including a lack of robust evidence of their effectiveness, delivery methods and acceptability by policy and farming systems [51]. Equitable access must be ensured, and regulatory frameworks for registration, distribution and integration into livestock production and Veterinary Services are still lacking. Clear guidance on appropriate use and expected outcomes is also needed, including whether these products are positioned as feed additives or as therapeutic interventions.

Metrics of success: how to measure effectiveness of antimicrobial stewardship programmes

Without clarity on a definition or understanding of what AMS is, how can indicators to measure AMS success be developed [37]? Most national surveillance programmes monitor quantities of antimicrobials imported or sold, while actual on-farm consumption is monitored far less frequently. Overall, the low adoption of on-farm monitoring reflects the high cost of gathering such data, which is logistically complex and may be constrained by weak infrastructure, fragmented production systems and limited farmer compliance. Sales and import data, the most commonly available data sources [78], do not include details on dose, duration, indication or outcomes; hence, they can measure changes in quantities of antimicrobials sold but not quality of AMU.

As one example of capturing broader AMS metrics, in Canada, sentinel terrestrial animal farms are enrolled in the national surveillance programme, the Canadian Integrated Program for Antimicrobial Resistance Surveillance, according to strict inclusion and exclusion criteria [79]. The farm-level surveillance captures information on dose, duration, route of administration, housing, vaccination status, disease status and reason for AMU [79]. For poultry and grower–finisher pigs, this information is captured via a questionnaire administered by the farm veterinarian, and on the same date, the veterinarian collects samples for bacterial culture and susceptibility testing [79]. The importance of this questionnaire is that information related to ‘reduce’, ‘refine’ and ‘replace’ is captured and can be analysed in conjunction with AMR

information, including effects of vaccines and other farm management activities. Despite strong inclusion and exclusion criteria, volunteer sentinel farm surveillance may still reflect participation bias and is difficult to scale up to include all farms. However, it yields rich, detailed data not available from other sources.

Another option for capturing information for stewardship would be to have an indication put on the prescription medication (should a system permit this information to be included and retrieved), which has been proposed to have many benefits, for example in helping with selection of antimicrobials and facilitating patient compliance and understanding [80]. In human medicine, the purpose on the label needs to respect confidentiality of the patient and must be expressed in lay language [80]. Additionally, the question could be asked, 'Have you used the antimicrobial according to an appropriate guideline?' This serves two purposes: i) administrative control (in that the prescriber needs to affirm their prescription is being administered according to a reference) and ii) providing a potential source of surveillance data. Such surveillance data would enable continuous scrutiny of how to do things better (i.e. the 'R' of review). This would require the existence of good-quality, locally relevant and accessible guidelines (while national guidelines provide standardised, evidence-based recommendations, local guidelines are crucial for incorporating local AMR patterns, available resources and specific animal disease circumstances). Similarly, in *Antimicrobial Stewardship Programmes in Health-Care Facilities in Low- and Middle-Income Countries: A WHO Practical Toolkit*, to evaluate the effectiveness of AMS, WHO further defined outcome measures (e.g. quantitative changes in AMU, economic outcomes, patient responses) and process measures (e.g. prescriptions in compliance with treatment guidelines) [34]. Tracking outcomes related to animal health, compliance with treatment guidelines, and economics in veterinary medicine has long posed significant challenges. The additional capture of more information could be adding to prescribers' time and effort; to address this, the tools need to decrease the workflow burden, and systems should be designed with this in mind [80]. In human medicine, electronic medical record systems integrated with clinical decision support tools that provide pre-populated treatment recommendations have been proposed to guide prescribing while reducing documentation burden [81,82].

As another alternative for measuring AMS, point prevalence surveys are more routine in human medicine and are being considered and tested for veterinary practices [81-83]. Point prevalence surveys typically involve capturing information for one day across multiple practices/clinics, though protocols have been tested for having multiple point prevalence surveys conducted either weekly or monthly in the same practice and then summarised annually [81,82]. Information on both prescriptions and infections can then be compared, which has been shown to be effective for measuring elements of AMS in both small animal and equine practices [81,82].

Like the measures proposed by WHO, recently James *et al.* [84] constructed useful ways of thinking about measures for AMS across One Health sectors: i) structural measures (e.g. governance and leadership), ii) process measures (access to treatment guidelines, availability of diagnostic tools) and iii) outcome measures (changes in antimicrobial sales/use – consumption, changes in AMR and clinical improvements) [84]. Some of the structural measures can be captured under tracking of implementation of national action plans (such as through the Quadripartite’s Global Database for Tracking AMR Country Self-Assessment Survey, and some of the outcome measures can be captured under national surveillance if in place; however, tracking process measures, quality of AMU and clinical improvements remains elusive at the global level.

Decision support tools to support antimicrobial stewardship

National and facility-level treatment guidelines are essential clinical decision support tools within AMS programmes. By standardising empiric and targeted therapy, these guidelines help optimise antimicrobial selection, dosing and duration, and they trigger pre-specified ‘review-and-revise’ prompts at critical junctures (e.g. 48–72 hours post-initiation or upon receipt of culture results). In animal health, the development and adoption of treatment guidelines have lagged in comparison to human health, particularly in food-animal medicine; by contrast, companion animal treatment guidelines are well established in several high-income countries [67,70]. Ideally, treatment guidelines should be developed by a multidisciplinary panel that formulates treatment recommendations based on comprehensive literature review (ideally using an appropriate evidence synthesis method such as Grading of Recommendations Assessment, Development and Evaluation [85]), aggregated clinical experience and expert consensus, and then updated regularly to reflect emerging evidence. Yet in practice, across most low-resource settings, where Veterinary Services for livestock are often privatised and decentralised [86], successful implementation of treatment guidelines remains elusive (although this is also true for many high-resource countries). Whether compliance with their use is best supported through incentive-based approaches, regulatory mandates or a combination of both is still an open question. Equally unresolved is how best to evaluate the impact of guideline-driven interventions on AMU and AMR in livestock systems, underscoring an urgent need for rigorous implementation research. A recent review of responsible use guidelines in 49 Organisation for Economic Co-operation and Development countries found that 37 countries had guidelines; however, in these countries, there were only 43 clinical guidelines intended for veterinarians and 37 non-clinical guidelines for non-veterinarians (e.g. farmers, farm workers) [87].

In hospitals, digital clinical decision support tools are increasingly deployed to provide physicians rapid access to up-to-date antimicrobial prescribing information at the point of care,

resulting in more appropriate empirical therapy across most facilities. In settings without comprehensive electronic records, mobile applications embedding local prescribing guidelines offer a pragmatic alternative in low-resource environments. Digital decision support tools have clear applicability to supporting AMU in food-animal medicine. Mobile and web-based platforms can embed species- and production system-specific AMU guidelines, allowing veterinarians and animal health workers to access recommended drug choices, dosages and withdrawal periods at the point of care on farms. For example, iCow in Kenya [88], already used by about two million smallholder farmers to access animal health and market information, could be extended to collect real-time disease data and embed AMS functionality, with treatment guidance modules, withdrawal period reminders and usage tracking dashboards delivering actionable recommendations directly into on-farm decision-making workflows.

Further, in healthcare settings, artificial intelligence algorithms now analyse large clinical datasets to identify resistance patterns and patient risk factors [89], thereby refining antimicrobial management; analogous precision livestock technologies are emerging on farms, where barn noise sensors can detect coughs in pigs for early respiratory disease alerts, and mobility, feeding and drinking monitors in cattle flag behavioural changes that prompt targeted intervention [90]. The implementation and acceptance of these digital support aids among veterinary health professionals depend on a broad range of contextual, regulatory, incentive-based, trust-related and interpersonal factors.

Practical antimicrobial stewardship experiences from various regions of the world

One key message that is essential to convey is that farmers, veterinarians and animal owners have been involved in AMS activities for a long time; the concept is not new, although use of the word stewardship may be. However, globally, improvements are needed in AMS to address the crisis of AMR, which involves an understanding of lessons learnt, successes and factors that lead to sustainable behavioural changes and enhanced AMS. There are many stories of successful AMS, a selection of which are presented in Boxes [1](#), [2](#), [3](#), [4](#), [5](#) and [6](#).

Themes that emerged from the case studies included leadership, collaborative learning, networks, the importance of surveillance for reviewing and refining AMS actions, sustained and sustainable actions, embracing AMS as part of good farming practices, and the idea of success with incremental improvements. The breadth of AMS activities across the regions reflects a needed component of AMS: it must be general enough to be understood widely, but also context specific to address the needs of a particular locality or sector [37]. From FAO's work in both Kenya and Vietnam, the participatory approach of Farmer Field Schools is akin to a participatory approach, previously called 'handshake stewardship', that has been employed in human medicine [113]. Handshake stewardship within a hospital involves a

personal approach to feedback (physician and pharmacist), lack of restriction or pre-approvals/prior authorisations, and a collaborative review of all antimicrobial prescriptions [113]. The work spanning many countries in Europe has shown that by reducing AMU, reductions in resistance in select bacterial species can occur, and that there are linkages between resistance in select bacterial species in animals and people.

Synthesising insights from case studies, stewardship history, AMS history and principles, decision support tools and measurement approaches, [Figure 3](#) highlights communication catchphrases that reflect core stewardship values.

Barriers and facilitators of antimicrobial stewardship in veterinary practice

In many settings, AMS is hindered by misaligned incentive structures, where farmers prioritise the rapid restoration of productivity while animal health practitioners derive income from treatments, including antimicrobials, thereby disincentivising non-antimicrobial options. As one UK cattle veterinarian noted, veterinarians sometimes prescribe against their own judgement because saying no to a farmer's request can result in the client seeking another veterinarian [114]. Realigning incentives by decoupling prescribing from dispensing, and by remunerating advisory and preventive services, could reduce profit-driven prescribing and refocus decisions on animal health outcomes. For example, Denmark's policy of prohibiting veterinarians from directly dispensing antimicrobials removes the financial reward for overprescribing, while aligning remuneration with advisory services rather than product sales helps ensure that decisions are driven by animal health needs rather than profit. Furthermore, clear benefit structures for producers are essential before expecting investment in AMS. Without tangible gains in animal health, productivity or profitability, farmers may find it difficult to justify absorbing costs when the benefits accrue largely to society rather than their own farms.

Effective regulation is a critical enabler of AMS, yet many regions suffer from weak compliance assessment, enforcement and oversight in the veterinary pharmaceutical sector. In many countries, the absence of strict controls on access, such as mandatory prescription requirements, means that in many settings antimicrobials can be obtained and used by farming communities with little oversight. Weaknesses in supply chain monitoring and pharmacovigilance further heighten the risk of substandard or counterfeit products, as well as the absence of essential medicines lists to guide use.

Diagnostics are another critical pillar of AMS, enabling evidence-based treatment decisions and reducing reliance on empirical AMU. However, access and utilisation remain constrained by multiple barriers, including the limited availability of affordable laboratory services,

shortages of trained personnel, unreliable sample transport systems, long turnaround times, and high, often unaffordable, cost. In many production systems, these constraints mean that treatment decisions are frequently made without diagnostic confirmation, increasing the likelihood of inappropriate or broad-spectrum AMU.

Beyond regulation and diagnostics, behavioural and cognitive factors such as training, prescribing habits, client expectations and professional culture also strongly shape AMS. Behavioural lessons from human medicine could be adapted for veterinary medicine. For example, a Dutch study in human medicine found that antimicrobial prescribing improved when using a behavioural approach that preserved prescriber autonomy by allowing physicians to choose their own improvement intervention [115]. Other behavioural approaches in human medicine, such as requiring justification/rationale in a medical record (e.g. for prescribing antimicrobials for upper respiratory tract infections) and financial rewards for providing a rationale for not prescribing antimicrobials have been shown to be effective [116,117]. Similarly, human factors also come into play with social value of animals and AMS: a study of AMU in dogs *versus* dairy cattle in three different countries found that, for example, ‘high-value’ animals received critically important or broad-spectrum antimicrobials rather than tailored or optimal AMU [118]. These examples illustrate the need for AMS initiatives and programmes to more deeply consider human factors, including education, attitude change and effective communication – especially listening more to farmers.

Gaps in education of veterinarians on AMS can lead to uneven awareness and persistence of suboptimal prescribing practices. Even when knowledge exists, fear of poor outcomes, client pressure and entrenched cultural norms might encourage imprudent AMU. However, according to a recent benchmarking study of Swiss companion-animal practices, veterinarians responded positively to peer comparison and demonstrated an interest in understanding how to improve their prescribing [119].

Despite awareness of the overall principles, the gap in communication of what actions constitute AMS was clearly articulated by one veterinary technician who is also a farmer at the 2021 One Health AMS Conference in Canada as follows: ‘There are no simple steps or actions producers or farmers can start implementing tomorrow or this evening. As a vet tech and producer, I know I should change my farming practices, but even I don’t know the first step’ [120]. Very recently, AMS communication has been criticised for creating a gap between ‘technical guidelines and real-world prescribing decisions’; to address this gap, language from the world of radiation therapy has been proposed (as low as reasonably achievable, or ALARA) [72]. With this thinking, the emphasis shifts to achieving infection control with minimal AMU (still emphasising effectiveness) rather than solely evaluating whether the AMU itself was appropriate [72]. A similar approach was the outcome of a recent salmon expert workshop

in Chile in which AMU was identified as a component of disease management; however, it was considered a 'last-resort intervention' and applied only after other measures (e.g. vaccination, selective breeding) were put into place and assessed [121].

An excellent example of effective communication about AMS can be found with the British Poultry Council's *Antibiotic Stewardship Report 2025* and associated postcards [122]. In these documents, the Council highlights not just the substantial success with outcome-type AMS measures (83% decrease in total AMU since 2012, 99% decrease in critically important antimicrobials since 2012), but the ways in which it achieved this, such as 'Health-led – not habit-led' AMU, data sharing, global alignment and building trust [122].

Definition of antimicrobial stewardship for animal health

Recently, Hibbard *et al.* [37] extracted select definitions of AMS from the literature from various settings (inclusive of definitions published in the Journal of the American Veterinary Medical Association [123], Dyar *et al.* [31], etc.); for animals they separated them by setting – companion animal or companion animal/food animal. The authors used boundary object theory to find common elements in these definitions, which yielded: i) flexibility in scope and scale, ii) temporal and collective moral responsibility ('responsibility' implies ethical aspects) and iii) the need for contextual contingency [37]. They proposed the following definition for AMS across One Health sectors: 'A concept relevant to and applicable by all (individuals, communities, and institutions) [scope and scale], aiming at using and prescribing antimicrobials in humans and animals in a way that ensures the availability of antimicrobials for individuals in the present day, as well as preserving antimicrobial effectiveness for current and future populations [collective and temporal responsibility]. The operationalisation of stewardship includes considerations of whether antimicrobials should be used, the ways in which antimicrobials are used, as well as the broader context within which these decisions are made [contextual contingency]' [37]. Scope and scale capture the breadth of what is encompassed (e.g. whether disease preventive measures are included) and whether the responsibility is at the individual or institutional level, locally, regionally or globally [37]. Contextual contingency was further subdivided into i) sectors (e.g. for animals – all animals, whether companion animals, sporting animals, livestock or aquaculture), ii) socio-cultural environments (e.g. for animals – all) and iii) settings (e.g. veterinary hospital, livestock farm) [37].

Capturing the history of the word stewardship, how it has been described and applied, and building on the work of Hibbard *et al.* [37], a practical definition for AMS in animal health can now be presented ([Box 7](#)).

The focus of this definition is on the purpose or destination (i.e. reducing AMR and maintaining antimicrobial effectiveness), with the imparting of responsibility ('commitment') rather than the route to get there (e.g. strategy, actions, guidelines). Putting this definition into action or operationalisation, then, can be specific to the target audience (e.g. companion animal owner, veterinarian), which does not detract from the communication of the essence of the definition ([Fig. 4](#)).

Building on the definition, AMS is a goal and objective for everyone. How this goal is achieved is context specific, constantly evolving and subject to continuous improvement. AMS for animals should be an all-embracing approach to protect all antimicrobials ([Fig. 2](#)), irrespective of the situation, where implementation will be specific to either the individual animal, individual human or group of animals (flock/shed of birds, feedlot, ponds of fish, etc.). In [Figure 2](#), the outer antimicrobial-free circle or world is for everybody – family, farmer, community – all antimicrobial stewards. The inner AMU region is ideally controlled by a veterinarian or other similarly licensed veterinary paraprofessional. Treatment guidelines fall within the inner box. The pivotal message is that all measures to reduce the need for antimicrobials are the responsibility of everyone.

Discussion

Since its earliest usage, the term 'stewardship' has conveyed the principles of preservation, responsibility and accountability. Its expansion across disciplines underscores a central truth: stewardship means protecting what matters most. Antimicrobials are no exception.

AMS principles are similar across human and animal medicine, but opportunities to apply them (particularly with respect to disease prevention, infection prevention and control, and water, sanitation and hygiene) are much greater for production-animal medicine: as veterinarians are engaged with keeping animals healthy on farms, often over the entire life cycle of animals from conception to death. For veterinarians, there is an obligation to implement AMS and address animal health and welfare and farm productivity. Elements of AMS have been employed in veterinary medicine for decades; however, AMR continues to increase (as noted particularly in human pathogens and foodborne pathogens, where the data are more routinely captured in surveillance activities) [40], reaching the highest levels of political attention [6]. How can people be encouraged to pick up existing guidelines or other decision-making tools and use them?

One way is through communication. As noted by Mendelson *et al.* [124] and true today, with respect to One Health and AMR, 'People from these disparate domains are talking past each other' [124]. Practical implementation of AMS can be communicated through the five Rs of responsibility, review, reduce, refine and replace. Many of the actions, particularly those listed

under 'reduce', such as biosecurity measures, are initiatives that veterinarians and farm personnel are already implementing, though perhaps not framed as AMS. And framing things as stewardship activities is an important step towards responsibility from an AMU perspective. Managing the health of animals appropriately involves the use of antimicrobials, but they should be used as little as possible, yet as much as necessary. Sparing use of antimicrobials can extend their life and effectiveness.

In the absence of an agreed-upon definition, it can be difficult to understand roles and communicate them with others [31]. Dyar *et al.* [31] acknowledge that this risks the term 'antimicrobial stewardship' becoming 'a meaningless catchword'. Combining lessons learnt through history, lessons from global case studies, experiences across human and animal health, and the proposal of a recent One Health definition for AMS [37], this article suggests that a modern definition of AMS in animal health should focus on the goal. The ways in which the goal is reached (operationalisation) should be outside the definition and specific to the target audience. A definition and other terminology around AMS need to be clear so that all audiences (i.e. those who are responsible) understand and can facilitate uptake of the principles, with the emphasis that the terminology itself should not be a barrier to action. In agreement with Hibbard *et al.* [37] and their boundary approach leading to a proposed One Health definition for AMS, the definition needs to be both i) broad/adaptable (to capture the different viewpoints from smallholder farmers in low- and middle-income countries through to intensive animal rearing operations in high-income countries) and ii) robust (to maintain the conceptual identity and components regardless of setting).

In the proposed definition, the phrasing 'optimising usage' may raise questions, such as 'optimal for what?' or 'optimal for whom?'. Optimising could mean for therapeutic success (bacterial cure), it could be related to the best choice of drugs to ensure the livestock farmer has an effective affordable option, or it could be related to the drug that facilitates consistent administration of the antimicrobial (e.g. route of administration and how often it is given can have implications for compliance). This article supports the merits of incorporating all these interpretations within this chosen word. The word 'optimal' or 'optimisation' generally is accepted to refer to maximising efficacy while minimising negative effects, which could include AMR [45], although critics have also noted that 'optimising' can incorporate elements of farmer/veterinarian profitability. 'Optimize' is included in WHO's 2015 *Global Action Plan on AMR* as one of the five pillars of the action plan ('to optimize the use of antimicrobial medicines in human and animal health') [125]. The same document, under 'Member State action', recommends: 'provision of stewardship programmes that monitor and promote optimisation of antimicrobial use at national and local levels in accordance with international standards in order to ensure the correct choice of medicine at the right dose on the basis of evidence' [125]. While it is acknowledged that 'optimise' or 'optimisation' may challenge the goal of using easily

communicable terminology, the term is widely recognised across disciplines and has been adopted by WHO for global communication.

Other barriers that need to be overcome are inappropriate incentives for AMU, lack of regulations or enforcement of existing regulations and lack of opportunities for education. Despite these barriers, the case studies from multiple regions of the world show local success stories with Farmer Field Schools through participatory methods, establishing platforms for sharing information, and the power of networks and having tools to monitor the effectiveness of AMS initiatives.

Efforts to reduce barriers to AMS should be grounded in an understanding of human behaviour, fostering ambition and a drive for improvement without discouraging motivation by setting goals that feel out of reach. Solving a problem as complex as AMR requires many small steps towards improving AMS. Individually a step may seem minor, but together they can create meaningful change [30]. There also needs to be effective communication that many aspects (particularly internal biosecurity) do not need to be labour intensive or cost prohibitive.

Participatory approaches that build ownership have been proven to be successful at reducing AMU (as evidenced in the case studies), in addition to providing other productivity benefits to livestock producers, in countries across different economies. These approaches include simplifying the situation to start conversations (i.e. 'getting in the door') with a subsequent layering of the priority actions. Finding ways to reduce human reluctance to change will result in the greatest benefits for AMS. Sustaining momentum will require proactive, well-designed strategies that anticipate and address competing priorities such as disease outbreaks and limitations in surveillance capacity or data availability. This requires active leadership involvement and engagement, enhanced collaborative networks, and seamless embedding of AMS as part of biosecurity and other animal health frameworks.

Conclusions

The conservation of valuable and precious resources lies at the core of human existence, and the concept of safeguarding antimicrobials as one such resource has been recognised for over a century. Under the United Nations Political Declaration on AMR, the world has been tasked with improving prudent and responsible use across humans, animals, plants/crops and the environment through stewardship. One way to achieve this is by having a global understanding that in animals, while more can be done, AMS principles are already being aligned to activities as a course of good animal rearing, and this must be stressed in clear communication. Having a globally agreed-upon definition of AMS in animals is an essential part of moving this forward, emphasising not just how these precious medications are used, but also what is being done to reduce the need for them.

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Box 1

Australia

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Antimicrobial stewardship in Australia's animal sector: evolution and key messages

Australia's livestock industries demonstrate how leadership drives meaningful action in AMS. Efforts trace back to the 1950s, as documented in the Australian Veterinary AMS Timeline [91]. While some progress was made over the decades, initiatives lacked national coordination. The release of Australia's first National AMR Strategy in 2015 [92] marked a turning point, prompting a unified AMS approach through partnerships between industry, government and researchers.

Motivation for action

At the 2015 strategy launch, AMR in animals was framed as a simplistic livestock misuse problem overlooking species-specific differences and Australia's robust legislation. This highlighted two priorities for livestock representatives: i) documenting AMS, AMR and AMU to enable evidence-based communication and foster constructive national dialogue and ii) addressing shared stewardship challenges while accounting for sectoral differences and operational constraints. Subsequent informal meetings among livestock representatives and experts became a platform for collaborative learning, input into AMS strategies, and knowledge exchange. By 2017, this group had evolved into an informal onboarding hub for AMS in the livestock industries, offering guidance and connecting new stakeholders to experts. Recognising the inefficiency of repeated efforts, members sought to formalise their collective expertise into accessible, evidence-based resources.

Platforms for knowledge exchange

This vision led to the inaugural Australian Veterinary AMS Conference in 2018. The conference provided a forum for cross-sector learning and collaboration on AMS initiatives and was accompanied by the first Animal Industries AMS Report [93]. This report outlined historical and current AMS practices for various livestock sectors, serving as a practical stakeholder reference. Additionally, the Australian Veterinary AMS Timeline [91] preserved historical records dating back to the 1950s, ensuring a lasting corporate memory for AMS efforts.

Formalising collaboration

In 2020, five major livestock industries – chicken meat, dairy, eggs, pork and red meat – formalised their collaboration through the Animal Industries' AMS Research, Development and Extension Strategy [94]. This framework facilitated the sharing of updates and evidence on AMR/AMS issues, leveraging resources and activities across sectors, and addressing local challenges, such as prioritising parasite resistance in sheep over bacterial AMR.

Translating antimicrobial stewardship into practice

A key national achievement was the development of an AMS infographic based on the internationally recognised 5Rs framework [95]. This tool was widely adopted, including in the 2018 Feedlot Antimicrobial Stewardship Guidelines [96] and the Australian Chicken Meat Federation AMS Report [97]. The Australian Veterinary AMS Conferences also facilitated peer-reviewed publications and sector-specific AMS initiatives such as government-supported AMR surveys and AMR Vet Collective training modules [98] for continuing education.

Lessons and ongoing challenges

Australia's AMS journey underscores the importance of a sector-led understanding of AMR issues, supported by expertise and genuine commitment to address real challenges and investment in platforms for sustained knowledge exchange and collaboration. Despite progress, maintaining AMS momentum remains challenging due to competing priorities like zoonotic disease outbreaks and limited surveillance data. Long-term sustainability will require continued leadership engagement, stronger networks and integration of AMS into broader biosecurity and animal health frameworks.

Box 2

Canada

Author: C.A. Carson

In Canada, largely based on surveillance data, the broiler chicken industry voluntarily banned the preventive use of a third-generation cephalosporin in hatching eggs and day-old chicks. This action story, described in detail elsewhere [99], changed AMU, successfully resulting in reduced AMR in chickens, chicken meat and people, although the story has not historically been framed specifically in an AMS lens.

Accompanying the banning of third-generation cephalosporins for disease prevention, the chicken industry developed a phased Responsible AMU Strategy [100], which banned all disease prevention uses of antimicrobials in select Categories of Importance to Human Medicine, based on a Canadian categorisation system [101]. It is worth noting that when third-generation cephalosporins, used to prevent *E. coli* omphalitis, were removed for disease preventive uses, the industry switched to using gentamicin and lincomycin-spectinomycin as the replacement antimicrobials because the disease pressure did not disappear. Following this switch, surveillance data indicated that while there was a successful drop in resistance to third-generation cephalosporins, there was an increase in gentamicin resistance – and associated multidrug resistance [102].

Subsequently, the preventive use of gentamicin and lincomycin-spectinomycin was also banned by the industry. At the time of writing, both the third-generation cephalosporin resistance and the gentamicin resistance have decreased. Of the five Rs of AMS, the story encompasses responsibility (veterinarians and producers), review (of two separate use practices) and reduce (reduced the disease preventive uses of Category I and II antimicrobials). Additionally, this story emphasises the need for timely and ongoing surveillance data to monitor the impacts of stewardship interventions (review and refine).

Box 3

Europe

Author: B. Freischem

European Commission Directorate-General for Health & Food Safety Directorate D – Medical Products and Innovation

In Europe, countries like Denmark, Norway and the Netherlands took early action on AMU in food-producing animals with a view to curbing AMR. The Danish Integrated Antimicrobial Resistance Monitoring and Research Programme was established by the Danish Ministry of Food, Agriculture and Fisheries and the Danish Ministry of Health in 1995 [103]. In Norway, a surveillance programme for drug prescribing in fish farming was introduced in 1989 [104]. The NORM-VET monitoring programme for AMR in animals, food and feed was established in 2000 [105]. In the Netherlands, sales of veterinary antimicrobials have been monitored since 1999 [106]. The voluntary European Surveillance of Veterinary Antimicrobial Consumption (ESVAC) project ran from 2009 to 2023 and reported on the sales of antimicrobial medicines used in animals across the European Union [107]. It spurred more European Member States into action, and by 2022, the last year reported on by ESVAC, a reduction in sales of veterinary antimicrobials of 53% since 2011 was reported for the 25 countries that consistently reported data between 2011 and 2022 [5]. Building on the success of the voluntary programme, mandatory reporting of sales and use data for antimicrobials in animals was introduced with Regulation (EU) 2019/6 on veterinary medicinal products.

Since 2012, the European Medicines Agency, the European Food Safety Authority and the European Centre for Disease Prevention and Control have jointly analysed the potential relationship between the consumption of antimicrobials by humans and animals and the occurrence of AMR. The fourth report, published in 2024, on data from 2019 to 2021 [108,109], shows that AMR has decreased in countries that have reduced the use of antimicrobials in both humans and animals. The susceptibility of *E. coli* to antimicrobials in humans and animals increases when there is an overall decrease in the consumption of antimicrobials [108,109]. In humans, the use of carbapenems, third- and fourth-generation cephalosporins, and quinolones is associated with resistance to these classes of antimicrobials in *E. coli* infections, whereas in food-producing animals, the use of quinolones, polymyxins, aminopenicillins and tetracyclines is associated with resistance to these antimicrobials in *E. coli* [108,109]. Importantly, the report also indicated that there is a link between bacterial resistance in humans and food-producing animals for certain bacterial species, such as *Campylobacter jejuni* and *Campylobacter coli*.

Box 4

Indonesia [110]

Author: R. Hibbard

French National Research Institute for Agriculture, Food and Environment, Host–Pathogen Interactions Unit (IHAP), National Veterinary School of Toulouse, University of Toulouse

In the Indonesian poultry sector, a qualitative case study examining the factors influencing AMU from the perspective of different stakeholders in the Indonesian poultry sector identified several barriers and opportunities to improving AMS in this sector.

Limited resources to support antimicrobial stewardship

Interviewed farmers and technicians reported using antibiotics to manage disease and, in specific ‘high-risk’ situations, negotiating between different information sources to guide their AMU. However, the difference between therapeutic and prophylactic use was often not clear, and there was variation in what farmers and their advisors deemed to be appropriate justification for AMU. This was made more challenging by the fact that formal AMU guidance was based mostly on high-income countries rather than local conditions. This suggests a need for better access to diagnostic tools and more locally appropriate guidance on when to use antibiotics.

Systemic challenges constraining antimicrobial stewardship

Many interviewed stakeholders across the poultry sector were aware of recent regulation to reduce AMU but faced a number of systemic constraints to changing AMU practices – most notably, considerable diagnostic uncertainty and external financial pressures. For example, recent increases in feed prices in Indonesia drove reduced expenditure on inputs. Interviewed farmers felt their purchase of lower-quality inputs had an impact on animal health, which had to be compensated for with increased AMU. These findings suggested that systemic factors not directly linked to AMU can have a significant impact and should be considered when developing policy or interventions.

A complex constellation of field actors implicated in antimicrobial use

A broad range of actors are implicated in AMU decision-making in Indonesia. The interviewed farmers reported that those they trusted the most were other farmers and technical services staff from poultry contractors (integrator companies). This suggests the importance of engagement with industry and the private sector alongside government Veterinary Services in efforts to implement AMS programmes and interventions and of providing a greater role for trusted field actors in driving AMS.

Good antimicrobial stewardship as part of what it means to be a 'good farmer'

Interviewed farmers and technicians were motivated to improve their AMU practices for a number of reasons, including to improve their farm management practices, as reduced AMU was considered to be a sign of 'good farming'. Consequently, it may be worthwhile to frame discussions around AMS as part of good farming practices more broadly, thus improving AMU interventions by engaging with farmers' conceptions of what it means to be a good farmer.

Box 5

Kenya

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Smallholder intensive poultry production systems are often heavily reliant on antimicrobials, used as quick fixes to compensate for limited investment in biosecurity. To address this challenge, FAO, together with local Veterinary Services and farmer groups, piloted a Farmer Field School programme on smallholder layer farms in Kenya between 2020 and 2021 [111]. The programme involved weekly sessions that combined practical, hands-on learning with discussions on husbandry, biosecurity (including vaccination) and prudent AMU.

The results were striking. Farmers who participated in the Farmer Field School programme were four times more likely to clean drinkers and feeders, were five times more likely to seek advice from animal health professionals when their flocks showed signs of disease, and spent around US\$ 8 less on antimicrobials compared to baseline levels over an eight-month period [111]. However, flock health indicators and investments in biosecurity products did not show measurable improvement as a result of participation in the programme [111]. The contrasting results underscore the inherent complexity of translating behavioural modifications into measurable biological outcomes.

While AMS interventions frequently yield early improvements in knowledge, attitudes and reductions in AMU, demonstrable gains in animal health often emerge only over longer periods. Such improvements typically require the cumulative effect of sustained preventive practices and the gradual disruption of entrenched disease transmission pathways.

Box 6

Vietnam

Another recent success story comes from Vietnam, where the Vietnamese Government with FAO and the United Kingdom's Fleming Fund piloted a Farmer School Community [112]. The structure of the Farmer School Community involved i) creation of a producer group that shared experiences and information and ii) experts who collected data (including AMU data) and shared the ideal production practices with the producer group [112]. A key principle was that even though there was diversity in the producer practices, the producers were not required to change anything and retained full decision-making over their farms, with an emphasis that improvements could be incremental [112].

The project was based on useful and easy-to-communicate objectives and foundations such as 'start with what farmers have' [112]. The result was that most participating flocks were healthy, with a substantial decrease (34%) in average AMU and a decrease in antimicrobial cost of 32% [112].

Box 7

Definition of antimicrobial stewardship for animal health

Commitment to preserving antimicrobial effectiveness by i) creating and sustaining conditions where antimicrobials are not needed, and ii) where use is necessary, optimising use to ensure maximum effectiveness and minimum resistance selection; within a culture of continuous improvement.

Perspectives et mise en pratique de la gestion des antimicrobiens en santé animale

C.A. Carson, D.M. Muloi & S.W. Page

Résumé

Dans le monde actuel, que signifie la gestion des antimicrobiens (GAM) ? Ce concept a-t-il la même signification pour les populations du monde entier et dans les différents secteurs de l'approche « Une seule santé » ? L'objectif de cet article est de résumer l'histoire et la terminologie de la GAM, les « cinq R » de la GAM ainsi que les indicateurs clés et outils d'aide à la décision, d'illustrer les concepts à travers des études de cas internationales, d'identifier les obstacles et les facilitateurs, et de proposer une définition standardisée de la GAM en santé animale.

Depuis les origines historiques et les usages du terme « gestion » (*stewardship*), les concepts de responsabilité, de reddition de comptes envers quelqu'un ou quelque chose et de préservation d'une ressource précieuse constituent des thèmes constants. Dans les domaines de la médecine humaine et vétérinaire, il existe des différences quant à l'étendue et au contenu de ce qui est considéré comme un usage prudent et responsable, ainsi que de la GAM. Bien que ces différences méritent d'être reconnues, elles résultent naturellement des contextes distincts de la pratique médicale dans ces secteurs. Fondamentalement, les mots servant à exprimer le concept de GAM sont moins importants que l'intention et le sens qu'ils véhiculent ; la langue ne doit pas constituer un obstacle à l'action.

Lorsque le champ de la GAM intègre les aspects des cinq R – responsabilité, révision, réduction, raffinement et remplacement – il reconnaît que de nombreux éléments de la GAM sont déjà présents dans les bonnes pratiques d'élevage animal. À travers le monde, les études de cas ont démontré des approches et initiatives de gestion hautement fructueuses dans des contextes économiques variés. Des défis subsistent, mais ils n'empêchent pas l'amélioration ni l'expansion mondiale de la GAM.

Les prochaines étapes pour faciliter les actions futures de GAM doivent porter sur la clarté et la cohérence de la communication sur la GAM en santé animale, y compris une définition acceptée à l'échelle mondiale. L'objectif de cet article est de promouvoir le concept de GAM opérationnelle en réduisant le recours aux antimicrobiens et, lorsque leur usage est nécessaire, en favorisant un usage responsable et prudent guidé par les principes et programmes de GAM. L'amélioration et l'optimisation de la santé animale constituent un levier essentiel de la GAM.

Mots-clés

Animaux – Gestion des antimicrobiens – Recommandations thérapeutiques – Usage prudent et responsable – Vétérinaire.

Perspectivas y aplicabilidad de la gestión de antimicrobianos en la sanidad animal

C.A. Carson, D.M. Muloi & S.W. Page

Resumen

En el mundo actual, ¿qué significa la gestión de antimicrobianos (GAM)? ¿Tiene el mismo significado para las personas de todo el mundo y en los distintos sectores de «Una sola salud»? El objetivo de este artículo es resumir la historia y la terminología de la GAM, los «cinco R» de la GAM, así como los indicadores clave y herramientas de apoyo a la decisión, ilustrar los conceptos mediante estudios de caso globales, identificar barreras y facilitadores, y proponer una definición estandarizada de la GAM en la sanidad animal.

Desde los orígenes históricos y los usos del término «gestión» (*stewardship*), los conceptos de responsabilidad, rendición de cuentas ante alguien o algo y cuidado de un recurso valioso han sido temas constantes. En la medicina humana y veterinaria existen diferencias en el alcance y contenido de lo que se considera un uso prudente y responsable, así como en la GAM. Si bien estas diferencias deben reconocerse, surgen de manera natural de los distintos contextos en que se ejerce la medicina en estos sectores. Fundamentalmente, las palabras que expresan el concepto de GAM son menos importantes que la intención y el significado que transmiten; el idioma no debe constituir un obstáculo para la acción.

Cuando el alcance de la GAM incorpora aspectos de los cinco R – responsabilidad, revisión, reducción, refinamiento y reemplazo – se reconoce que muchos elementos de la GAM ya están presentes en las buenas prácticas de cría animal. En distintas regiones del mundo, los estudios de caso han demostrado enfoques e iniciativas de gestión altamente exitosos en diferentes contextos económicos. Existen desafíos, pero no impiden la mejora ni la expansión global de la GAM.

Los siguientes pasos para facilitar acciones futuras de GAM deben abordar la claridad y coherencia en la comunicación sobre la GAM en animales, incluida una definición aceptada globalmente. El objetivo de este artículo es promover el concepto de GAM práctica reduciendo la necesidad de uso de antimicrobianos y, cuando su uso sea necesario, fomentando un uso responsable y prudente basado en los principios y programas de GAM. La mejora y optimización de la sanidad animal constituyen una herramienta clave de la GAM.

Palabras clave

Animales – Gestión de antimicrobianos – Recomendaciones terapéuticas – Uso prudente y responsable – Veterinaria.

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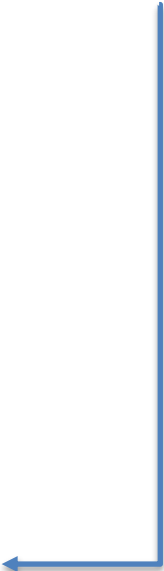
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Table I

Comparison of definitions or descriptors for responsible/prudent use and antimicrobial stewardship by global organisations and Hibbard *et al.* [37]

Organisation	Responsible/prudent use definition or description	Antimicrobial stewardship (AMS) definition or description
World Organisation for Animal Health (WOAH, founded as OIE)	<p>Definition: no dictionary-style definition</p> <p>Description of the objectives of responsible and prudent veterinary medical use (found in WOAH's <i>Terrestrial Animal Health Code</i>, Chapter 6.10., 'Responsible and prudent use of antimicrobial agents in veterinary medicine' [2]:</p> <ol style="list-style-type: none"> 1. Preserve the effectiveness of antimicrobial agents used in veterinary and human medicine and their safety in animals. 2. Comply with the ethical obligation and economic need to keep animals in good health. 3. Prevent or reduce transfer of resistant microorganisms or resistance determinants within animal populations, between animals, humans, and the environment. 4. Protect human health by ensuring the safety of food of animal origin with respect to residues of antimicrobial agents.' <p>'In order to achieve the objectives of responsible and prudent veterinary medical use of antimicrobial agents, a range of measures intended to improve animal health and animal welfare while preventing or reducing the selection, emergence and spread of antimicrobial resistant microorganisms and resistance determinants in animals, humans and environment should be implemented. These measures include promotion of good animal husbandry practices, hygiene procedures, biosecurity, vaccination strategies, access to laboratory testing, and alternatives to the use of antimicrobials, which can help to minimise the need for antimicrobial use in animals.'</p>	<p>Definition: no dictionary-style definition</p> <p>Description: many aspects of AMS are encompassed by proposals for measures to achieve responsible and prudent use (see bottom of column directly to the left), without specifically using the term AMS</p> 

Organisation	Responsible/prudent use definition or description	Antimicrobial stewardship (AMS) definition or description
Food and Agriculture Organization of the United Nations (FAO)	<p>Definition: no dictionary-style definition</p> <p>Description: The FAO manual <i>Prudent and Efficient Use of Antimicrobials in Pigs and Poultry</i> [32] contains the following description of prudent use: 'The prudent and medically effective use of antibiotics comprises several elements: a) Phasing out use of antibiotics as growth promoters and avoiding regular preventive use of antibiotics. b) Avoiding use of the Highest Priority Critically Important Antimicrobials for human medicine in animals and adhering to the OIE List of Antimicrobials of Veterinary Importance. c) Only using antibiotics based on a diagnosis of disease by a veterinarian or other animal health professional and only for authorised indications. d) Striving for individual treatment of animals with the correct dose and duration and avoiding using antibiotics for group treatments except for poultry flocks, especially via feed. e) Using only quality-assured pharmaceuticals and always consulting an animal health professional before use. f) Disposing of unused and expired antibiotics in a proper way.'</p>	<p>Definition: no dictionary-style definition</p> <p>Description: The FAO manual <i>Prudent and Efficient Use of Antimicrobials in Pigs and Poultry</i> [32] lists the actions needed to implement prudent use: <ul style="list-style-type: none"> • awareness and education; • governance and regulation; • key regulations include: <ul style="list-style-type: none"> – prescription-only access to antimicrobials; – ban on antimicrobials for growth promotion; – enforced withdrawal periods before animal products enter the food chain; – quality control of veterinary pharmaceuticals; – institutional capacity for compliance with regulations; – good health and management practices to prevent disease. </p>
World Health Organization (WHO)	<p>Prudent use definition: In the <i>Global Principles for the Containment of Antimicrobial Resistance in Animals Intended for Food</i> [33]: 'Usage of antimicrobials, which maximizes therapeutic effect and minimizes the development of antimicrobial resistance.'</p>	<p>AMS definition: In <i>Antimicrobial Stewardship Programmes in Health-Care Facilities in Low- and Middle-Income Countries: A WHO Practical Toolkit</i> [34], AMS is defined as: 'A coherent set of actions which promote the responsible use of antimicrobials. This definition can be applied to actions at the individual level as well as the national and global level, and across human health, animal health and the environment.'</p>

Organisation	Responsible/prudent use definition or description	Antimicrobial stewardship (AMS) definition or description
		<p>Within this toolkit, WHO further defines an AMS programme as follows: ‘An organizational or system-wide health-care strategy to promote appropriate use of antimicrobials through the implementation of evidence-based interventions.’</p> <p>Aims of AMS programmes:</p> <ul style="list-style-type: none"> • ‘to optimize the use of antibiotics; • to promote behaviour change in antibiotic prescribing and dispensing practices; • to improve quality of care and patient outcomes; • to save on unnecessary health-care costs; • to reduce further emergence, selection and spread of AMR; • to prolong the lifespan of existing antibiotics; • to limit the adverse economic impact of AMR; and • to build the best-practices capacity of health-care professionals regarding the rational use of antibiotics.’
United Nations Environment Programme (UNEP)	Definition: no dictionary-style definition	Definition: no-dictionary style definition
Quadripartite (WHO, WOA, FAO, UNEP)		<p>Definition: no dictionary-style definition</p> <p>Description: The Quadripartite <i>Draft Global Framework for Development & Stewardship to Combat Antimicrobial Resistance</i> [35] describes AMS as follows: ‘... an overarching term that includes practices to foster appropriate/prudent use in human and animal health and plant protection.’</p>

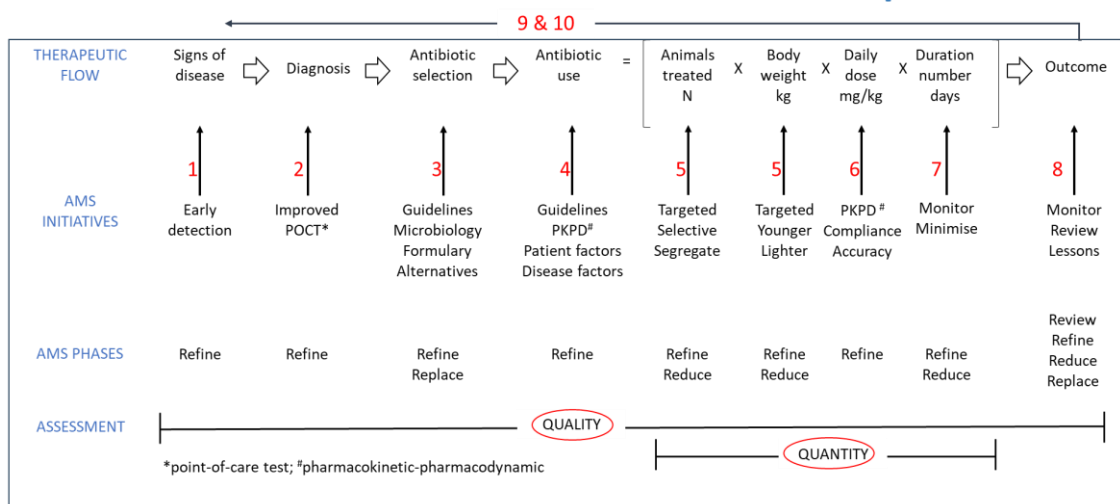
Organisation	Responsible/prudent use definition or description	Antimicrobial stewardship (AMS) definition or description
		The goal of stewardship is to improve the quality and cost-effectiveness of care and patient/animal outcomes, and decrease the further emergence and spread of AMR'
Proposed One Health definition for AMS (Hibbard <i>et al.</i> [37])	Definition: 'A concept relevant to and applicable by all (individuals, communities, and institutions) [scope and scale], aiming at using and prescribing antimicrobials in humans and animals in a way that ensures the availability of antimicrobials for individuals in the present day, as well as preserving antimicrobial effectiveness for current and future populations [collective and temporal responsibility]. The operationalisation of stewardship includes considerations of whether antimicrobials should be used, the ways in which antimicrobials are used, as well as the broader context within which these decisions are made [contextual contingency].'	

AMS is directed at protecting an irreplaceable resource while balancing effective treatment of bacterial infections and minimisation of antimicrobial resistance selection.

Ten considerations can help achieve this balance ...

1. early disease detection
2. accurate diagnosis at point of care
3. refined antibiotic selection
4. guideline-informed treatment protocol
5. targeted animal treatment
6. refined daily dose
7. response-informed duration of treatment
8. critical appraisal of outcome
9. design and implementation of improved IPC plans (no infection means no AMU), &
10. progressive measurement and benchmarking of AMU, AMR, animal health and welfare.

Elements of antimicrobial stewardship



Continuous improvement feedback loop

Figure 1

Elements and chronology of implementation of antimicrobial stewardship for animals [45]

- AMR: antimicrobial resistance
- AMS: antimicrobial stewardship
- AMU: antimicrobial use
- IPC: infection prevention and control

ANTIMICROBIAL STEWARDSHIP PRESERVING ANTIMICROBIAL AGENTS

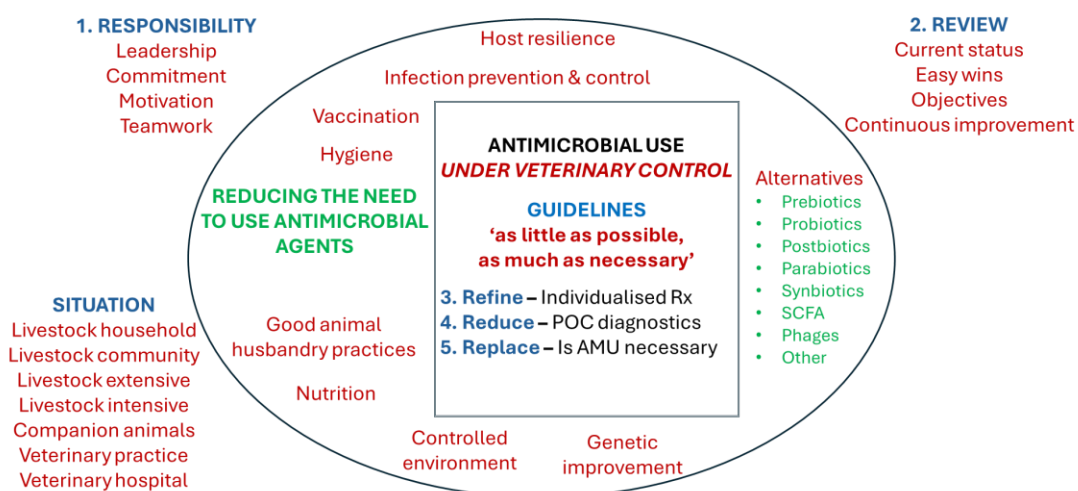


Figure 2

The universe of antimicrobial stewardship in animals

Note: the blue font reflects the 5Rs of stewardship; the green font indicates ways of reducing the need to use antimicrobials

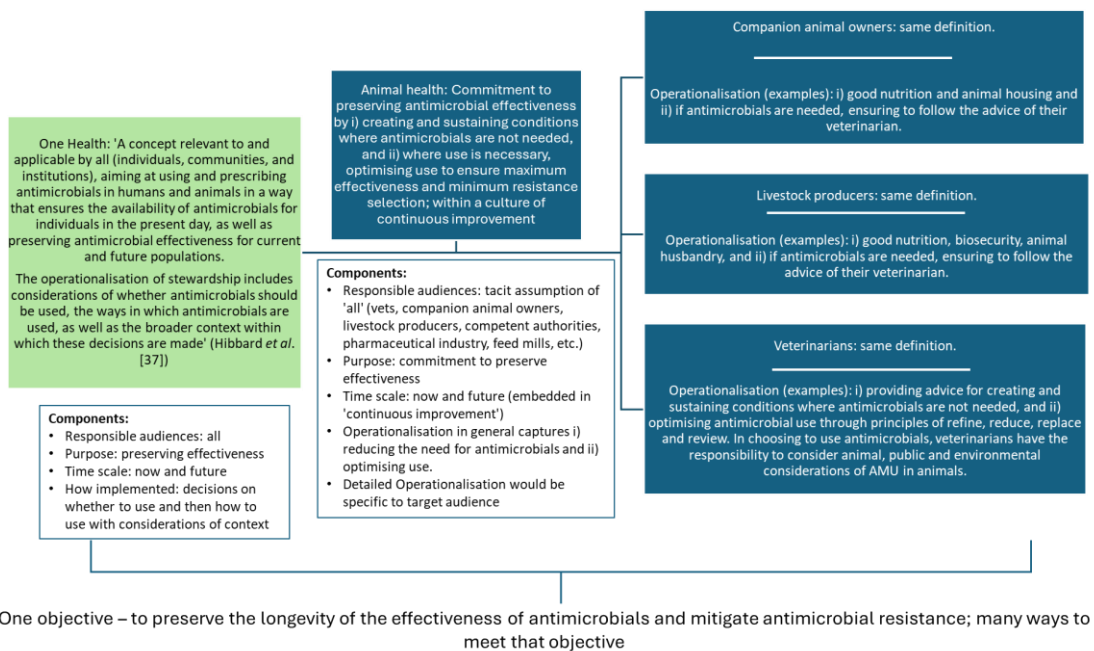
- AMU: antimicrobial use
POC: point of care
Rx: prescription
SCFA: short chain fatty acids



Figure 3

Phrases useful for communicating aspects of antimicrobial stewardship

Graphics generated in Wordart.com



AMU: antimicrobial use

Figure 4

Arriving at a proposed definition of antimicrobial stewardship in animal health for selected target audiences (animal owners and veterinarians)