Canada has an opportunity to address antimicrobial resistance through COVID-19 recovery spending

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Summary
Antimicrobial Resistance (AMR) causes more than a million deaths globally per year due to infections incurable with currently available antibiotics. Failing to effectively address AMR will have significant negative consequences for Canadians and the Canadian economy. Canada is behind on allocation of required funding and nationally coordinated AMR mitigation strategies relative to other high-income countries. A Pan-Canadian AMR action plan and development of a new governance model is pending. Recent AMR-specific funding commitments are significant but fall short while distribution of funds indicate a siloed approach. Canada could initiate progress towards AMR mitigation through incorporation within the scope of budget allocations intended for COVID-19 recovery and mitigation efforts. We discuss the following components for inclusion: development of infectious disease diagnostics and therapeutics; antimicrobial stewardship interventions in long-term care and Indigenous communities; environmental monitoring of AMR; comprehensive antimicrobial use, and AMR surveillance; and support for capacity-building in low and middle-income countries.

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Keywords: Antimicrobial resistance; Canada; Governance; Federal budget; Federalism; Surveillance; Antimicrobial stewardship; Resistant bacteria; Antibiotic development

Introduction
The COVID-19 pandemic has demonstrated the disastrous consequences of not having viable treatments for infectious diseases. Antimicrobial resistance (AMR) presents a similar challenge, wherein the spread of antimicrobial resistant bacteria lessens our ability to treat infectious diseases with current medicines. Worldwide, an estimated 1.27 million people died due to AMR in 2019, amounting to more deaths than from HIV/AIDS, breast cancer, and malaria in the same year. An estimated 13,000 Canadians would die each year when resistance approaches 40%, which is comparable to the yearly number of deaths caused by COVID-19 in Canada to date. Profound economic losses are to be expected if resistance continues on the current trajectory. Experts are calling for the inclusion of AMR in the development of a global pandemic treaty. Despite the urgency, Canada has not responded sufficiently to make a full-fledged impact on AMR domestically or globally in comparison to other high-income countries. Currently, Canada remains the only G7 nation not to have released a concrete national action plan with timelines and measurable outcomes. A recent initiative to develop and implement an AMR governance model has not been fulfilled. Canada, unfortunately, is not on track to meet the goals set out in its Pan-Canadian Framework for Action against AMR.

An environmental scan examining Canadian federal and provincial government interventions to reduce antimicrobial use (AMU) in humans concluded that available fiscal, regulatory, and legislative policy levers had not been fully utilized, and funding commitments to tackle AMR were so far insufficient, especially for action within Canada. In comparison to fellow G7
member states, Canada has so far not provided a plan to work towards preparedness for the “silent pandemic” of AMR, or concrete investment and incentive strategies for stimulating antibiotic development. Canada has, however, outlined the opportunities that the 2017 Pan-Canadian Framework for Action - a comprehensive, One Health plan which came out of a multi-stakeholder consultation process would present when implemented. Following the most recent G7 meeting in 2022, Canada promised to “spare no effort” to address AMR; however, mechanisms to tackle the issue of fragmented action and the absence of central coordination are regrettably missing.

It must be duly noted that Canada faces many challenges to implementing a coordinated national AMR response due to its federated nature of government, wherein responsibility for healthcare oversight and delivery lies with the provinces and territories. Nevertheless, at the federal level Canada has taken on initiatives related to AMR including working internationally with the World Health Organization (WHO) with rolling out the global action plan, launching the Canadian Antimicrobial Resistance Surveillance System (CARSS), regulating of AMU in animals by requiring veterinary oversight, and launching awareness campaigns. But overall, the urgency of the issue and the need for rapid action and elevation of ongoing work has not been fully recognized, notwithstanding dedicated – albeit modest – funding commitments.

In response to the profound economic losses in many sectors and the strain on health systems caused by the COVID-19 pandemic, governments around the world have allocated significant investments to COVID-19 recovery and mitigation. Spending amounted to $15 trillion USD worldwide in mid-2021, and the Canadian government had spent $340 billion by the end of 2021. In keeping with this focus, the federal budget for 2021 aimed to “finish the fight” against COVID-19 and was commendably comprehensive in its approach to ensure large scale investments in many areas of health, the economy, and the environment. This budget allocated $28.6 million towards AMR efforts that would be distributed to the federal health portfolio over five years: to reduce inappropriate prescribing and to monitor the emergence of AMR. We acknowledge this budget prioritization; however, it mirrors much of Canada’s earlier response to AMR which has been critiqued for being siloed and small-scale. Additionally, the absence of a larger, more comprehensive and adequately funded plan for AMR suggests a failure to recognize the role of COVID-19 in exacerbating AMR. The subsequent federal budget for 2022 signals a “return to normal” that focuses more on the current geopolitical situation as well as economic growth, and provides no follow-up or improvements to previous AMR funding commitments: AMR mitigation remains poorly integrated into COVID-19 recovery efforts. Moreover, the 2021 budget allocations are to be reviewed and potentially scaled back.

An effective AMR response requires a One Health approach that considers the interrelationships between humans, animals, and the environment, as well as coordinated action across provinces and territories, jurisdictions, and sectors that are implicated in AMR mitigation. A multi-pronged approach is required, similar to the plan of action for COVID-19 mitigation and recovery put forward in 2021. Currently, many different organizations across Canada are working to enhance a One Health AMR response, often collaboratively with other sectors; however, with no overarching or pan-Canadian focus, or centralized coordination. Operationalizing the existing Pan-Canadian Framework for Action against AMR through an action plan would have the most direct and immediate impact on AMR mitigation, as it would mobilize strategic action in all One Health domains facilitated by multi-stakeholder collaboration. While the Public Health Agency of Canada (PHAC) launched an AMR Taskforce in October 2021, which is intended to provide federal leadership and support coordinated multisectoral action on AMR, it has yet to put a plan in motion. In the absence of an operationalized and fully funded AMR action plan, we identify components of recent COVID-19 investment promises within which AMR mitigation strategies can be built in to achieve incremental progress. At this critical moment for human, animal, and planetary health, Canada’s federal government should stay the course: it should fulfil all of the promised multi-year commitments made in Budget 2021, and include AMR-specific spending within promised investments in Budget 2021 and 2022.

A. Investments in infectious disease diagnostics and therapeutics

As part of ensuring the health and well-being of Canadians, in 2021 the Canadian federal government allocated $2.2 billion over seven years to strengthen Canada’s bio-manufacturing and life sciences sector. Specific innovation funding and incentivizing strategies have long been sought to mitigate the rise of AMR. We highlight three key technological advancements that would fight the spread of AMR and could be supported through this potential spending commitment.

1) Rapid diagnostic tests offer point-of-care analysis of causes of infection that allow for rapid results and quicker diagnoses. Presently, antimicrobial susceptibility tests (ASTs) are defined as “tedious” and have long turnaround times of several hours to days, encouraging empirical therapy and antibiotic overuse. The federal government should leverage the momentum brought on by the pandemic to support innovation in domestic and international companies to develop rapid point-of-care tests that are more sensitive, cost-effective, and
affordable. This would be especially useful in the outpatient sector where testing capacity is limited and where roughly 90% of antibiotic prescribing occurs.\textsuperscript{24,25} It is essential that support for innovation is accompanied with strategies to overcome adoption and implementation challenges.\textsuperscript{26} Emerging evidence suggests that reimbursement and affordability is a barrier to optimal adoption of diagnostic technologies in several countries.\textsuperscript{27,28} Supporting companies with conducting high-quality large-scale outcomes research that demonstrates the clinical and economic benefits of the diagnostic test would contribute to rapid adoption.\textsuperscript{29,30}

ii) Modern medicine is highly dependent on antimicrobials to deliver quality healthcare and treat infectious diseases.\textsuperscript{31} Currently, there is a lack of new antimicrobials in the development pipeline, because of lower profitability gained for pharmaceutical companies in comparison to the manufacture of other drugs.\textsuperscript{31} Within the pharmaceutical and biotechnology industries, research and development of new antimicrobials can be promoted through two mechanisms: (1) “push” incentives at the early stages of the R&D pipeline, to support the initial discovery and development of new antimicrobials, and (2) “pull” incentives to support entry of new antimicrobials into the market (incentives which must be delinked from sales volumes to support responsible use of new antimicrobials).\textsuperscript{31,32} Coordinated and targeted large-scale government investments into R&D changed the course of COVID-19, by incentivizing the rapid development of medicines and vaccines to counteract the disease.\textsuperscript{10} In 2019, Canada invested about $21 million USD out of the world’s $1.49 billion USD in R&D investments, sparking calls from experts for more substantial investments.\textsuperscript{6} As a comparison, the 2016 Review on AMR estimates between $800 million and $1.3 billion USD as the most realistic and attractive model of market entry reward to developers of new antibiotics, in addition to $2 billion USD over 5 years in dedicated global funding for AMR innovation.\textsuperscript{11} As an international comparison, the UK and U.S. governments propose to invest £100 million and $3 billion USD, respectively, to incentivize antibiotic development.\textsuperscript{6} Canada should explore the benefits of delinked market entry rewards to incentivize antimicrobial development, as well as integrate funding for research grants and global non-profit partnerships to support antibiotic R&D.\textsuperscript{6}

iii) Vaccines have played a dramatic role during the COVID-19 pandemic by preventing infection and protecting communities at risk. Deploying vaccines as a tool to combat AMR would be effective in preventing infections and unnecessary AMU in both humans and animals.\textsuperscript{33} Vaccines are highly specific in comparison to antimicrobials and can be developed to target and act against strains of disease that are more susceptible to resistance.\textsuperscript{34} Currently, the development of vaccines for AMR bacteria such as Staphylococcus aureus, Clostridioides difficile, and Mycobacterium tuberculosis, are hindered because of a lack of sustained funding to develop, test, and license.\textsuperscript{35} Boosting the research and use of mRNA technology for bacterial infections could lead to reduced costs and time for vaccine development.\textsuperscript{36} Further, vaccines for key infections in food animals and aquaculture could underpin a reduction in AMU in agriculture, which accounts for 79% of AMU in Canada.\textsuperscript{25,26} The federal government has already pledged $3.4 billion to secure COVID-19 vaccines and to support Canadian-based pharmaceutical companies.\textsuperscript{10,37} Additionally, the construction of a new biologics manufacturing facility was recently made possible through a public-private partnership.\textsuperscript{10} These investments could be utilized to support the development and distribution of infectious disease vaccines in both humans and animals beyond the current target of COVID-19. Tackling particular challenges to vaccine effectiveness in animals, such as species-specificity, that may not be pursued by pharmaceutical companies due to low return on investments, could be overcome through public funding support to incentivize the development of safe and effective vaccines.\textsuperscript{10}

B. Improvement of surveillance and antimicrobial stewardship in Indigenous communities

The 2021 federal budget also promised to commit $18 billion over five years to improve the quality of life and increase opportunities for Indigenous communities.\textsuperscript{38} Indigenous Peoples in Canada have poorer health outcomes relative to the Canadian population as a whole due to decades of neglect, underfunding and, especially, structural drivers of health and disease including settler colonialism.\textsuperscript{39} Additionally, this population faces limited healthcare access, and many receive care for infections from small community care settings, including nursing stations in First Nations communities that operate in isolation from current Canada-wide surveillance systems.\textsuperscript{40} One means of improving Indigenous health outcomes would be to address the high burden of communicable diseases, including diseases in which drug resistance has been observed (e.g., tuberculosis (TB), methicillin-resistant S. aureus (MRSA)).\textsuperscript{3} Another would be enhancing surveillance systems for rural and remote regions, including First Nations communities, where comprehensive surveillance data is limited. A recent study found a high prevalence of AMU for diseases such as skin and soft tissue infections in First Nations populations.\textsuperscript{41} Tuberculosis is another disease that disproportionately affects Indigenous communities,\textsuperscript{41} although extensively drug-resistant TB is rare in Canada, it could become an issue in the future.\textsuperscript{1} Indeed, experts have called for a comprehensive infection prevention and control strategy to help improve Indigenous health.\textsuperscript{41} Evaluating antibiotic prescribing and use in
First Nations communities is another challenge because especially in remote communities, antibiotics may be provided by nursing staff without a prescription from a pharmacy or consultation with a physician that would facilitate tracking of prescribed antibiotics. Targeting funds towards Indigenous-led antimicrobial stewardship interventions, such as healthcare provider and patient education, and the development of data infrastructure for surveillance systems, could contribute to the detection and prevention of antibiotic- and antimicrobial-resistant infections, as well as appropriate prescribing in Indigenous communities.

C. Reducing antimicrobial use in long-term senior care settings

The federal government has placed great emphasis on protecting seniors following the onset of the COVID-19 pandemic, and the 2021 budget has allocated $3 billion over 5 years to supporting provincial and territorial implementation of standards in long-term care. This is in addition to the $1 billion Safe Long-term Care fund intended to help provincial and territorial governments improve infection, prevention, and control measures in long-term care settings. Part of this effort should include addressing the high percentage (50–75%) of inappropriately prescribed antimicrobials in this setting. Adverse events and medication toxicity in this population have been linked to inappropriate antimicrobial prescribing and unnecessarily prolonged treatment with antimicrobials. A high level of uncertainty around the diagnosis of infection in the elderly population, off-site prescribing by physicians without “bedside” discussion, and expectations from family, have been cited as factors leading to inappropriate prescription and use of antibiotics. Prescribing levels are more often related to the prescriber and culture of the institution than treatment needs. Therefore, part of the allocated funds could go towards supporting provinces and territories with the implementation of antimicrobial stewardship interventions, including standardized guidelines, quality indicators, and building incentives for appropriate antimicrobial prescribing in the long-term care setting. There is currently no formal program to evaluate stewardship interventions in the community care setting nationwide. Provincially-developed guidelines could be adapted to build national accreditation standards for antimicrobial stewardship programs in long-term care settings, similar to what is done in acute care hospitals.

D. Monitoring environmental reservoirs for resistant bacteria

The 2021 federal budget allocates $25.6 million over 5 years for Statistics Canada and Environment and Climate Change Canada to create a registry of all ecosystems in Canada, i.e., a census of the environment, and to monitor environmental trends. Integrating methods for monitoring the environment for resistant bacteria and evaluating the impact of these microbes on human health is crucial for understanding AMR in Canada. The environment holds AMR genes—acquired through maintenance of AMR bacteria—which can be transmitted through animals and/or agriculture to humans. Likewise, human activity and waste from facilities (e.g., manufacturing plants or healthcare facilities) can contaminate the environment with antimicrobial resistant organisms, AMR genes and antimicrobials, and can transmit resistant organisms from humans to non-human animals. This intersection of wastewater discharge, sewage, farm manure, and animal production facilities run off, potentially amplifies and selects for resistant microbes. Additionally, the increase in the use of biocides caused by the COVID-19 pandemic requires the allocation of funds towards understanding the mechanisms of spread and impact on human and animal health. Although the reduction of AMU would be the most effective method of minimizing resistance, there may be room to improve current wastewater treatment processing and target sources contributing to contamination. Networks such as the COVID-19 Wastewater Coalition launched during the pandemic, which successfully coordinates COVID-19 surveillance efforts across the country, could be leveraged and repositioned more broadly to also include AMR bacterial detection and surveillance within the allocated funds, at least within incorporated communities.

E. Addressing the urgent need for comprehensive integrated antimicrobial resistance surveillance and antimicrobial use data

Budget 2021 allocated $41.3 million to be spent over 6 years to improve data infrastructure and data collection in the ageing population specifically in the areas of supportive care, primary care, and pharmaceuticals. Notably, the 2021 budget emphasized collecting data and improving data quality in a variety of sectors, such as childcare and the entrepreneurship ecosystem. Similarly, there is an urgent need for more comprehensive AMR/AMU surveillance data in Canada. Overall, Canada’s surveillance of AMR/AMU has been described as fragmented and uncoordinated. Nine surveillance systems exist, belonging to various jurisdictions, and which collect data only for a select number of bacteria, and prevalence data from some organizations. Environmental, community care, and companion animal data are not collected. Surveillance data from across the One Health continuum are essential to monitor the prevalence of AMR/AMU and to develop
benchmarks. Funding allocated to data infrastructure development is needed to integrate existing data and build connections with key stakeholders not so far included, and to strengthen and/or establish integration within and between sectors. Resources are also needed to implement reporting standards, ensure the quality of data, and making data accessible to researchers and policymakers.9

The Canadian livestock industry has seen many gains in reducing AMU through effective government policies and improvements in animal management practices; however, the impact on farming costs, animal health and production is not known.1 A national surveillance system is needed to gain a better understanding of the impact of changing farming practices to tackle AMR and to facilitate further research on best practices to reduce AMU.1 The Canadian Agriculture Partnership that already provides support for Canadian farmers, and which is expected to be renewed in 2023, could include funding for a comprehensive reporting system.17

In 2021 the Canadian government also allocated $400 million in funding over 6 years to launch a pan-Canadian Genomics Strategy.18 It is essential that part of this funding be used to take advantage of the use of genomic sequencing to control and detect AMR genes in Canada.51 Dedicated funding for existing Canadian genomic repositories and support for integration with international databases, would be beneficial for tracking and modelling resistance ecology.51

F. Supporting low- and middle-income countries with the implementation and funding of national AMR action plans

AMR is a global issue that transcends borders due to trade and the movement of people and animals, some of whom may carry drug-resistant bacteria across borders.12 A study of the global burden of AMR in 2019 reinforced that funding and capacity-building around the world is essential to combat AMR.1 Low- and middle-income countries (LMICs) have the highest burden of AMR, and require capacity-building support including implementing national action plans, building laboratory infrastructure for microbiological testing, and antimicrobial stewardship programs. Canada has contributed to international AMR efforts by engaging in policy and expert forums, endorsing UN Tripartite activities, and funding the Joint Programming Initiative on Antimicrobial Resistance (JPIAMR); however, ongoing and significant funding commitments to support LMICs tackle AMR have not been made.16 The federal government has allocated $1.4 billion over five years in the 2021 budget towards “building a safer, resilient, and equitable world” and international assistance. The 2022 federal budget included a promise to increase assistance in the next decade, on top of the $2.7 billion already allocated to LMICs to fight the COVID-19 pandemic.17,55

In accordance with the WHO’s Global Leaders Group on Antimicrobial Resistance recommendations, Canada could build financial support for AMR-specific funding sources for LMICs. Such sources include, for example, the Multi-Partner Trust Fund (MPTF) which, despite contributions from the UK, Sweden, the US, and the Netherlands, remains underfunded.16 Experts also call for Canada’s support for CARB-X and GARDP (Global Antibiotic Research and Development Partnership), two global non-profit partnerships that are targeting the development and access of antibiotics for infections most acute in LMICs.8 Funding commitments are especially vital given the growing challenges AMR will pose to achieving food security, poverty reduction, economic growth and other Sustainable Development Goals.45

Conclusions

The Canadian government has an opportunity to revisit and spark further progress within key components of AMR mitigation, through the funding promises made to address COVID-19 mitigation and recovery. Canada urgently needs to make significant headway on AMR action and could become a key player in the global fight against AMR, if it so chooses. The recent launch of a development process for an international instrument on pandemic prevention, preparedness, and response – which could include AMR – will again test Canada’s commitment to investing in domestic and global health efforts in this area. We also echo the call for the swift release of a Pan-Canadian Action Plan on AMR that would guide action and assist with costing a response. We reiterate that operationalizing an action plan would bring into play the most comprehensive effort to tackle AMR, including the implementation and improvement of infection prevention and control practices, among other strategies beyond the scope of this article. Following through with an implementation plan for a new governance body based on recently developed model options would ensure future efforts are coordinated across the country.12

Contributors

D.S.S. conceptualized, completed all literature searches, drafted the original manuscript, and incorporated all edits and comments. D.S.S. was Research and analysis lead for a Public Health Agency of Canada (PHAC) initiative which developed governance models for a Pan-Canadian AMR Network. I.B. conceptualized, reviewed and edited the manuscript. I.B. was governance consultant for the AMR Network initiative funded by PHAC. M.P. conceptualized, reviewed and edited the manuscript. M.P. was Project Director of the AMR Network initiative funded by PHAC. H.W.B., S. Hillier, S. Hindmarch, J.S.W., G.D.W., and A.M.M. were Steering Committee members for the PHAC initiative to develop governance models for a Pan-Canadian AMR Network. H.W.B., S. Hillier, S. Hindmarch, J.S.W., G.D.W., and A.M.M. provided additions to the concept, reviewed and edited the manuscript. A.M.M. and G.D.W. acquired funding for the AMR Network initiative.
Declaration of interests
H.W.B., S. Hillier, S. Hindmarch, J.S.W. have no conflicts to declare. G.D.W. received individual honoraria from ENABLE and ENABLE-2 as a member of project management team for European consortium in antibiotic delivery. G.D.W. was a keynote speaker at June 2021 event for L’Association des médecins microbiologistes infectéologistes du Québec. G.D.W. has individual stock options with Prokaryotic Inc. Company is focused on new antibiotic discovery. G.D.W. received support for his institution from Public Health Agency of Canada for the present manuscript. A.M.M. received support for institution from Public Health Agency of Canada for the present manuscript. I.B. received support for the present manuscript from PHAC and was paid for providing governance consulting services for the Pan-Canadian AMR Network project. M.P. received support for the present manuscript as an employee of Sinai Health System and through a grant funded by the Public Health Agency of Canada. D.S.S. received support for the manuscript and was paid for the work on the Pan-Canadian AMR Network project.

Acknowledgement
The authors’ (D.S.S., I.B., and M.P.) time was supported by a Public Health Agency of Canada grant (#1920-HQ-000058). The funding source had no role in the concept of the manuscript or decision for submission.

References
1 Antimicrobial Resistance Collaborators. Global burden of bacterial antimicrobial resistance in 2019: a systematic analysis. Lancet. 2022;399(10325):629–655.
2 Council of Canadian Academies [Internet]. Ottawa: Council of Canadian Academies. When antibiotics fail: the expert panel on the potential socio-economic impacts of antimicrobial resistance in Canada. Available from: https://eca-reports.ca/wp-content/uploads/2018/10/When-Antibiotics-Fall-1.pdf; 2019. Accessed April 14, 2022.
3 Wilson LA, Van Katwyk SR, Weldon I, Hoffman SJ. A global pandemic treaty must address antimicrobial resistance. J Law Med Ethics. 2021;49(4):688–691.
4 AMR Control: Overcoming Global Antimicrobial Resistance [Internet]. Carlet J, Crémioux A, Brun-Buisson C, et al. The french approach to fighting antibiotic resistance: a constant and coordinated effort since 2000. Available from: http://resistancecontrol.info/2016/government-engagement/the-french-approach-to-fighting-antibiotic-resistance-a-constant-and-coordinated-effort-since-2000/; 2017 May 19. Accessed April 14, 2022.
5 HHS.gov [Internet]. Assistant secretary for health. PACCARB timeline. Available from: https://www.hhs.gov/asl/advisory-committees/paccarb/about-paccarb/timeline/index.html; 2022 March 7. Accessed April 14, 2022.
6 University of Calgary [Internet]. Hollis A. Policy brief no. 2: increasing Canada’s support for the development of new antimicrobials. Available from: https://research.ucalgary.ca/sites/default/files/teams/17/Policy_Brief_No_2_FINAL.pdf; 2021 May 14. Accessed April 14, 2022.
7 Gov.uk [Internet]. HM Treasury. G7 Finance Ministers’ statement on actions to support antibiotic development. Available from: https://www.gov.uk/government/publications/g7-finance-ministers-statement-on-actions-to-support-antibiotic-development; 2021 December 13. Accessed April 14, 2022.
8 Canada, House of Commons Standing Committee on Health. A study on the status of antimicrobial resistance in Canada and related recommendations: report of the Standing Committee on Health. 42nd Parl., 1 sess. Report 16. Available from: https://www.ourcommons.ca/Committees/en/HESA/StudyActivity/studyActivityId-9572825; 2018. Accessed April 14, 2022.
9 Van Katwyk S, Grimming J, Hoffman S. Ten years of inaction on antimicrobial resistance: an environmental scan of policies in Canada from 2008 to 2018. Health Policy. 2020;154(5):687–693.
10 World Health Organization [Internet]. Monitoring global progress on addressing antimicrobial resistance. Available from: https://www.who.int/publications/i/item/monitoring-global-progress-on-addressing-antimicrobial-resistance; 2018. Accessed April 14, 2022.
11 Public Health Agency of Canada [Internet]. Strengthening governance of the antimicrobial resistance response across One Health in Canada. Available from: https://www.canada.ca/en/public-health/news/2021/07/statement-from-the-minister-of-health-on-the-antimicrobial-resistance-amr-network-report.html; 2021 July 20. Accessed April 14, 2022.
12 Government of Canada [Internet]. Tackling antimicrobial resistance and antimicrobial use A Pan-Canadian framework for action. Available from: https://www.canada.ca/en/health-canada/services/publications/drugs-health-products/tackling-antimicrobial-resistance-use-pan-canadian-framework-action.html; 2017. Accessed April 14, 2022.
13 World Health Organization [Internet]. OECD, WHO, FAO, OIE. Tackling antimicrobial resistance: ensuring sustainable R&D. Available from: https://www.oecd.org/g20/summits/hamburg/Tackling-Antimicrobial-Resistance-Ensuring-Sustainable-RD.pdf; 2017 June 29. Accessed August 30, 2022.
14 Government of Canada [Internet]. Prime Minister of Canada Justin Trudeau. G7 Leaders’ Communiqué. Available from: https://pm.gc.ca/en/news/stories/2022/06/28/g7-leaders-communique; 2022 June 28. Accessed August 30, 2022.
15 Government of Canada [Internet]. Progress report on the 2015 federal action plan on antimicrobial resistance and use. Available from: https://www.canada.ca/en/public-health/services/publications/drugs-health-products/progress-report-2015-federal-action-plan-antimicrobial-resistance-use.html; 2018. Accessed April 14, 2022.
16 Inter-American Development Bank [Internet], Watkins G, Edwards G. Achieving sustainable recovery: criteria for evaluating the sustainability and effectiveness of COVID-19 recovery investments in Latin America and the Caribbean. Available from: https://publications.iadb.org/en/achieving-sustainable-recovery-criteria-evaluating-sustainability-and-effectiveness-covid-19; 2021. Accessed April 14, 2022.
17 Government of Canada [Internet]. Budget 2022: a plan to grow our economy and make life more affordable. Available from: https://budget.gc.ca/2022/home-accueil-en.html; 2022. Accessed April 14, 2022.
18 Government of Canada [Internet]. Budget 2021: a recovery plan for jobs, growth, and resilience. Available from: https://www.canada.ca/en/department-finance/news/2021/04/budget-2021-a-recovery-plan-for-jobs-growth-and-resilience.html; 2021. Accessed April 14, 2022.
19 Knight GM, Glover RE, McQuaid CF, et al. Antimicrobial resistance and COVID-19: intersections and implications. Elife. 2021;10:e66439.
20 Kariyawasam RM, Julien DA, Jelinski DC, et al. Antimicrobial resistance (AMR) in COVID-19 patients: a systematic review and meta-analysis (November 2019-June 2021). Antimicrob Resist Infect Control. 2022;11(1):45.
21 World Health Organization [Internet]. Global action plan on antimicrobial resistance. Available from: https://www.who.int/publications/i/item/9789241509763; 2015. Accessed April 14, 2022.
22 Emory University Global Health Primer [Internet]. What is a rapid diagnostic test (RDT)? Available from: http://www.globalhealthprimer.emory.edu/targets-technologies/rapid-diagnostic-test.html; 2022. Accessed April 14, 2022.
23 Kaprou GD, Bergpica I, Alexa EA, et al. Rapid methods for antimicrobial resistance diagnostics. Antibiotics. 2021;10(2):209.
24 Vasa LA, Hytinen VP, Lahtinen OH. Modern tools for rapid diagnostics of antimicrobial resistance. Front Cell Infect Microbiol. 2020;10:308.
25 McCubbin KD, Anholt RM, de Jong E, et al. Knowledge gaps in the understanding of antimicrobial resistance in Canada. Front Public Health. 2021;9:726484.
26 Trevas D, Caliendo AM, Hansen K, et al. Diagnostic tests can stem the threat of antimicrobial resistance: infectious disease professionals can help. Clin Infect Dis. 2021;211(1):e89–e90.
27 Wurcel V, Perche O, Lesteven D, et al. The value of companion diagnostics: overcoming access barriers to transform personalised diagnostics of antimicrobial resistance. Front Cell Infect Microbiol. 2022;10:308.
28 Caliendo AM, Gilberge D, Gnochco CC, et al. Better tests, better antibiotic treatment: a position statement. J Antimicrob Chemother. 2020;75(7):2090–2091.
29 Slater J, Shields L, Racette RJ, et al. The emergence of precision therapeutics: new challenges and opportunities for Canada’s health leaders. Healthc Manage Forum. 2015;28(6 Suppl):S33–S39.
30 Bubela T, Gold ER, Goel V, et al. Open drug discovery of anti-virals critical for Canada’s pandemic strategy. Facets. 2020;5(1):1019–1036.

31 Dutescu IA, Hillier SA. Encouraging the development of new antibiotics: are financial incentives the right way forward? A systematic review and case study. Infect Drug Resist. 2021;14:415–434.

32 Camar J, Leszczyński R, Tang PK, et al. To push or to pull? In a post-COVID world, supporting and incentivizing antimicrobial drug development must become a governmental priority. ACS Infect Dis. 2021;7(8):2029–2042.

33 AMR Review.org [Internet]. O’Neill J. Tackling drug-resistant infections globally: final report and recommendations. Available from: https://amo-review.org/sites/default/files/160518_Final%20paper_with%20cover.pdf; 2016 May. Accessed April 14, 2022.

34 Alghamdi S. The role of vaccines in combating antimicrobial resistance (AMR) bacteria. Saudi J Biol Sci. 2021;28(12):7505–7510.

35 World Health Organization [Internet]. Bacterial vaccines in clinical and preclinical development 2021: an overview and analysis. Available from: www.who.int/publications/i/item/9789240652451; 2021. Accessed April 14, 2022.

36 Hoeleiz K, Bielke L, Blake DP, et al. Vaccines as alternatives to antibiotics for food producing animals. Part 1: challenges and needs. Vet Res. 2018;49(1):64.

37 Government of Canada [Internet]. Prime Minister of Canada Justin Trudeau. Prime Minister announces funding to advance the development of Canadian COVID-19 vaccine technologies. Available from: https://pm.gc.ca/en/news/news-releases/2020/10/23/prime-minister-announces-funding-advance-development-canadian-covid; 2020 October 23. Accessed April 14, 2022.

38 Government of Canada [Internet]: Prime Minister of Canada Justin Trudeau. New measures to ensure the supply of future vaccines and therapies against COVID-19. Available from: https://pm.gc.ca/en/news/news-releases/2020/08/31/new-measures-ensure-supply-future-vaccines-and-therapies-against; 2020 August 31. Accessed April 14, 2022.

39 Reading C. Structural determinants of Aboriginal peoples health. In: Greenwood de L & L, ed. Determinants of Indigenous peoples’ health beyond the social. 2nd ed. Canadian Scholars Press; 2018.

40 Jeong D, Nguyen HNT, Tyndall M, et al. One Health evaluation of antimicrobial use and resistance surveillance: a novel tool for evaluating integrated, One Health antimicrobial resistance and antimicrobial use surveillance programs. Can Commun Dis Rep. 2022.

41 Leis JA, Born KB, Ostrow O, et al. Prescriber-led practice changes that can bolster antimicrobial stewardship in community health care settings. Can Commun Dis Rep. 2020;46(1):1–5.

42 Yau JW, Thor SM, Tsai D, et al. Antibiotic stewardship in rural and remote primary health care: a narrative review. Antimicrob Resist Infect Control. 2021;10(1):105.

43 Kruger SZ, Bronskill SE, Jelfs I, Steinberg M, Morris AM, Bell CM. Evaluating and prioritizing antimicrobial stewardship programs for nursing homes: a modified Delphi panel. Infect Control Hosp Epidemiol. 2020;41(9):1028–1034.

44 Daneman N, Bronskill SE, Gruneir A, et al. Variability in antibiotic use across nursing homes and the risk of antibiotic-related adverse outcomes for individual residents. JAMA Intern Med. 2015;175(8):1331.

45 Dyar OJ, Pagani L, Pulcini C. Strategies and challenges of antimicrobial stewardship in long-term care facilities. Clin Microbiol Infect. 2015;21(1):10–19.

46 NHS England [Internet]. Technical guidance for refreshing NHS plans 2018/19 annex B: information on the quality premium scheme. Available from: https://www.england.nhs.uk/publication/technical-guidance-annex-b-information-on-quality-premium/; 2017. Accessed April 14, 2022.

47 Leis JA, Born KB, Ostrow O, et al. Prescriber-led practice changes that can bolster antimicrobial stewardship in community health care settings. Can Commun Dis Rep. 2020;46(1):1–5.

48 Public Health Ontario [Internet]. Antimicrobial stewardship essentials. Available from: https://www.publichealthontario.ca/en/health-topics/antimicrobial-stewardship-long-term-care; 2022. Accessed April 14, 2022.

49 RQHealth.ca [Internet]: Accreditation Canada. Antimicrobial stewardship. Available from: https://www.rqhealth.ca/service-lines/master/files/8842129_RROP_Medication_Use_Antimicrobial_Stewardship_Feb2014.pdf; 2014. Accessed April 14, 2022.

50 Wellcome Trust, Centres for Disease Control and Prevention (U.S.) & UK Science & Innovation Network [Internet]. Initiatives for addressing antimicrobial resistance in the environment: current situation and challenges. Available from: https://wellcome.org/sites/default/files/antimicrobial-resistance-environment-report.pdf; 2018. Accessed April 14, 2022.

51 Canadian Water Network [Internet]. COVID-19 wastewater coalition. Available from: https://owen-rce.ca/covid-19-wastewater-coalition/; 2022. Accessed April 14, 2022.

52 Haworth-Brockman M, Saxinger LM, Mizzaga-Rodriguez M, et al. One Health evaluation of antimicrobial use and resistance surveillance: a novel tool for evaluating integrated, One Health antimicrobial resistance and antimicrobial use surveillance programs. Front Public Health. 2021;9:693703.

53 Engelhardt R, Wright GD. Beating superbugs: innovative genomics and policies to tackle AMR. Genome Canada. Available from: https://www.genomecanada.ca/sites/genomecanada/files/16-115_gps_policybrief_nol1_e_web.pdf; 2016. Accessed April 14, 2022.

54 Tsegaye L, Huston P, Mil liken R, Hanniman K, Nesbath C, Noad L. How is an international public health threat advanced in Canada? The case of antimicrobial resistance. Can Commun Dis Rep. 2016;42(11):221–226.

55 Government of Canada [Internet]. Canada’s aid and development assistance in response to the COVID-19 pandemic. Available from: https://www.international.gc.ca/world-wide/issues-development-enjeux_developpement/global_health-sante_mondiale/; 2021. Accessed April 14, 2022.

56 AMR Leaders.org [Internet]: Global Leaders Group on Antimicrobial Resistance. Financing to address antimicrobial resistance. Available from: https://www.amrleaders.org/docs/library/financing-to-address-amr.pdf?sfvrsn=572722d7_1&download=true; 2021. Accessed April 14, 2022.