LEAVING THE LAB

Tracking the Decline in AMR R&D Professionals

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amr INDUSTRY ALLIANCE
UNITED AGAINST ANTIMICROBIAL RESISTANCE

Contents

Executive Summary

Researchers Are Leaving the AMR Field – Even as the Threat Rapidly Grows

Antimicrobial resistance (AMR) is among the top causes of death worldwide and one of the greatest health threats of our time. AMR is estimated to have caused 1.27 million deaths and been associated with 4.95 million deaths in 2019.[1] However, these devastating figures are just the beginning of the challenge ahead. If unaddressed, it is estimated that AMR may cause as many as 10 million deaths every year by 2050, while costing the global economy a cumulative $100 trillion.[2]

Yet global action is still falling far short of the urgency, coordination, and investment needed to deliver new antimicrobial treatments and defuse the AMR threat. Despite important recent milestones such as the 2016 UNGA High-Level Meeting on AMR, which catalyzed a number of actions on AMR, we continue to see slow progress on work to contain AMR.

However, there's a key aspect of the challenge that remains largely overlooked: the AMR field has been steadily losing vital scientific and research talent for more than two decades. This "brain drain" could further impede progress for years to come, even if governments enact policies such as pull incentives to help bring private investments back to antimicrobial R&D. By the time the world decides to act on AMR, there may be few researchers and organizations left with the expertise, skills, and infrastructure to deliver the innovation needed to combat the problem.

In response, the AMR Industry Alliance conducted this review of publicly available data on the state of AMR R&D talent and output to provide an overview of the current state of the AMR R&D field. The topline results are alarming – adding greater urgency to our collective AMR response:

The AMR R&D workforce is limited and declining, even as the threat grows.

Overall, we estimate there are approximately 3,000 AMR researchers currently active in the world (estimated range of 1,218 – 4,726); compared to as many as 46,000 for cancer and 5,000 for HIV/AIDS. This comes as the number of deaths due to AMR continues to climb around the world.

The number of AMR researchers has significantly declined over the past 20+ years.

The total number of authors on all AMR publications has declined from a high of 3,599 in 1995 to 1,827 in 2020, alongside an overall decline in publications.

AMR research output is many times lower than fields like cancer and HIV/AIDS.

The decline in AMR research stands in stark contrast to fields like HIV/AIDS and cancer. In 2022, there were 35 times more papers published on cancer than priority bacteria, and in 2022, there were 20 times more patents awarded for cancer than antibiotics. HIV/AIDS research also outperforms AMR in these categories.

These trends are driven by the broken market for antimicrobials, a lack of investment in the field, and loss of expertise due to job changes and retirements. Major pharmaceutical companies and smaller biotech companies have struggled with a lack of market incentives, while private investors and governments direct funds to other areas.

As a result, many passionate AMR researchers are being forced to leave the field – draining invaluable knowledge, expertise, and dedication at the very moment when we need it most.

Global leaders must create solutions now to ensure a strong, stable R&D workforce that can pioneer new breakthroughs and spearhead an effective response to the growing AMR crisis.

Landscape

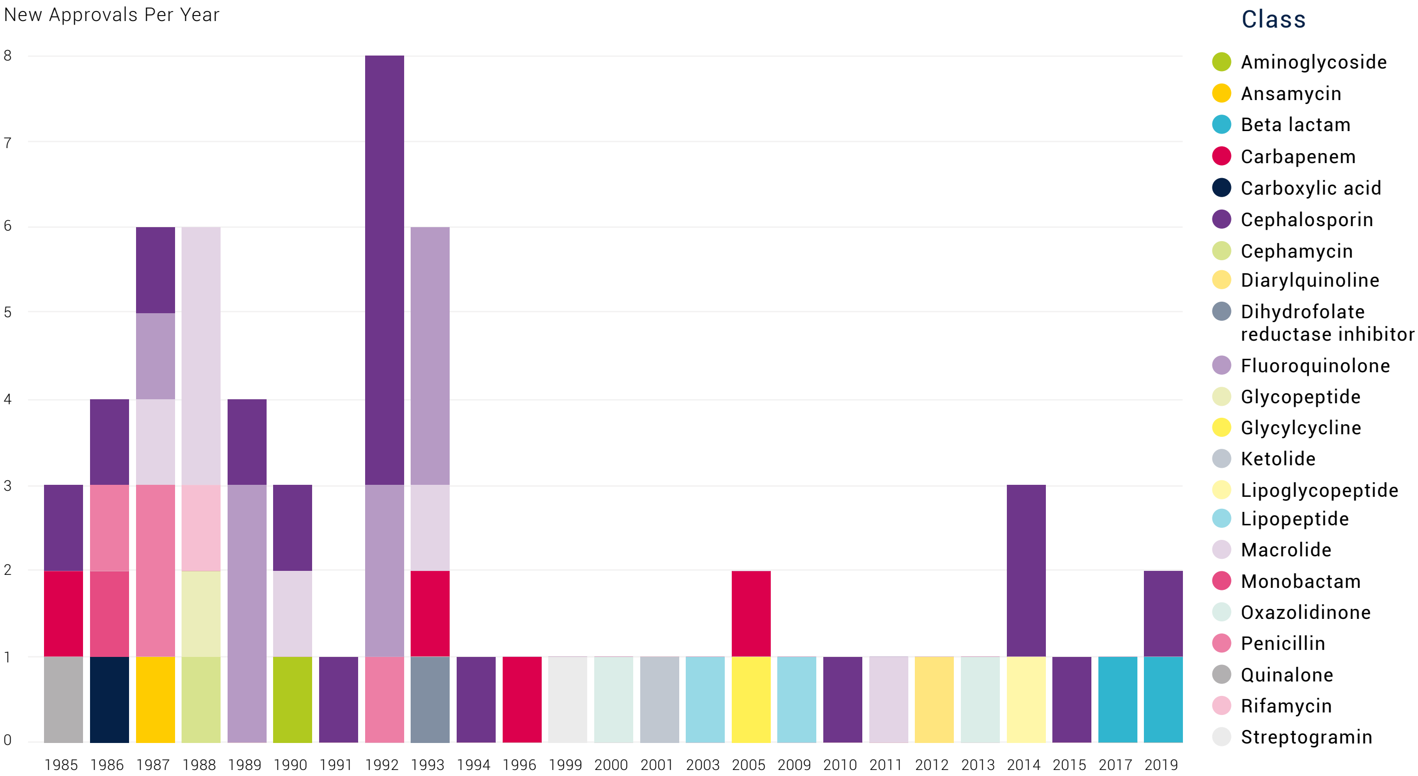
The Unsustainable Impacts, Risks, & Costs of AMR

According to the World Health Organization (WHO), AMR is a top 10 public health threat and already one of the top causes of death worldwide.[1] The impacts and costs of AMR are growing worse every year – putting our world on a grave trajectory. Infections that are easily treated now will become more deadly as resistance spreads. Without new antimicrobial drugs, AMR could turn routine medical procedures and small injuries into potentially life-threatening events.

The world urgently needs a steady stream of new antimicrobial treatments to help contain the AMR crisis. However, **the market for new antimicrobials is broken.** It faces an inherent challenge: the threat of AMR means that new antimicrobials should be used only when needed, which limits sales volumes. Further, antimicrobials are largely genericized and not highly valued by health systems. Hence, prices, revenues, and sales volumes tend to be low, which in turn makes it challenging for companies to invest in the long-term, risky R&D needed to produce new drugs.

For example, Figure 1 shows year-by-year releases of new antibiotics. In the 1980s and early 1990s, multiple new antibiotics were introduced each year. However, since the early 1990s, most years have seen the release of just one new drug,[3] and there are a number of high-profile cases where the associated companies successfully launching an antibiotic have eventually gone bankrupt.[4,5,6]

FIGURE 1. ANNUAL FDA APPROVALS OF ANTIBIOTICS HAVE FALLEN FOR DECADES



Governments around the world have started to discuss in earnest the need for incentives to support a sustainable pipeline of antimicrobials. However, the current trends of the AMR research workforce[1] highlighted in this report suggest that timely investments are critical to not only advance R&D for urgently needed antimicrobials but also to retain talent and expertise.

[1] When referring to an "AMR Researcher," we are including roles such as research/lab assistants, post-doctoral researchers, principal investigators, specialists who conduct clinical trials, medical professionals who also participate in research (such as ID doctors), microbiologists, and any other person in industry, academia, or healthcare that contributes to the research and eventual development of antimicrobials.

Challenge

The AMR Field Is Losing Vital Scientific Talent

To date, few studies have examined the state of the AMR research workforce. To fill this gap, the AMR Industry Alliance conducted a comprehensive review of publicly available data and expert interviews to estimate the total number of AMR researchers. Additional details are available in "Appendix: Methodology."

Our research shows a field that has been in steady decline over the last two decades, across publications, patents, and, most importantly, the number of researchers working and publishing in the field. The decline is especially significant when compared to cancer and HIV/AIDS.

The Number of AMR Publications & Authors Is Declining

Our findings from papers published based on clinical and randomized controlled trial (RCT) data indicate that antimicrobial research, particularly late-stage work, is slowing down – and has been for nearly two decades. This can be seen in both approvals of new antimicrobials as well as in AMR and antimicrobial-related publication, author, and patent data.[7]

As Figure 2 shows, the annual number of publications in these areas has been falling since around 2000, with a peak of 586 papers on antimicrobials in 1995. By 2022, there were only 187 papers published on antibiotics, and just 29 on antifungals.

There have also been significant declines in patents for antibiotics and antifungals in recent years. As of 2022, 115 patents were rewarded related to antibiotics, while just 15 patents were awarded for antifungals.

When we examined specific authors of AMR publications, we found the total number of people involved in antibiotic and antifungal publications has declined since the 1990s – down from a peak of around 3,600 in 1995 to 1,800 by 2020.

Finally, there has also been a decline in researchers with three or more publications – investigators with a focused research interest in AMR. This number has declined since the mid-1990s, falling from a peak of ~1,300 to less than 700 by 2020.

FIGURE 2. AMR PUBLICATIONS HAVE DECLINED FOR 20+ YEARS

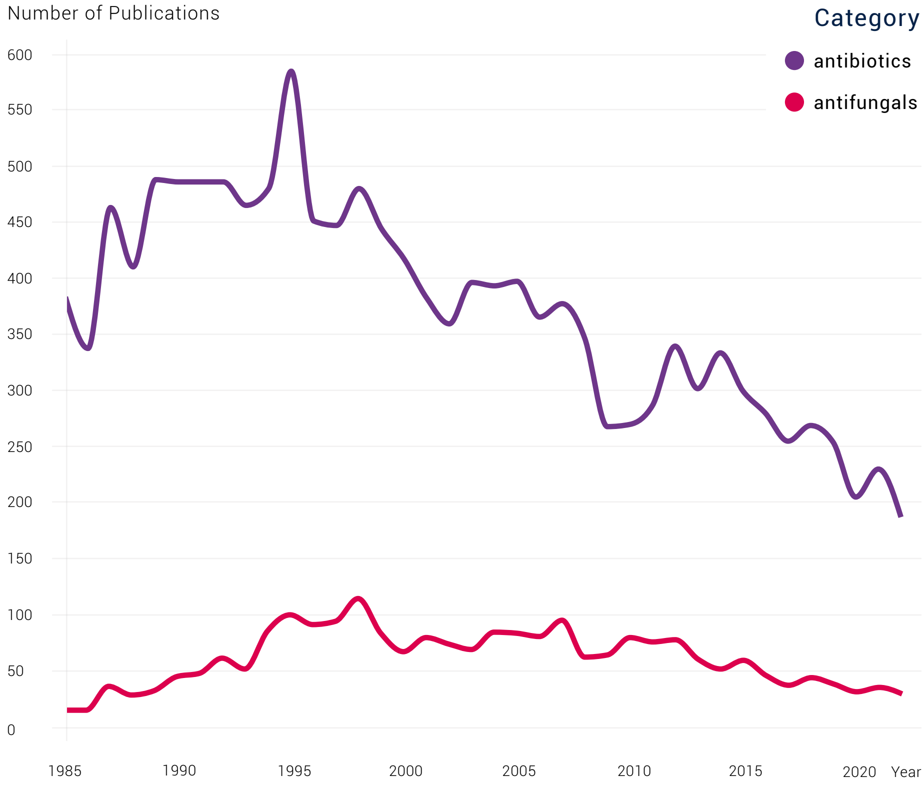
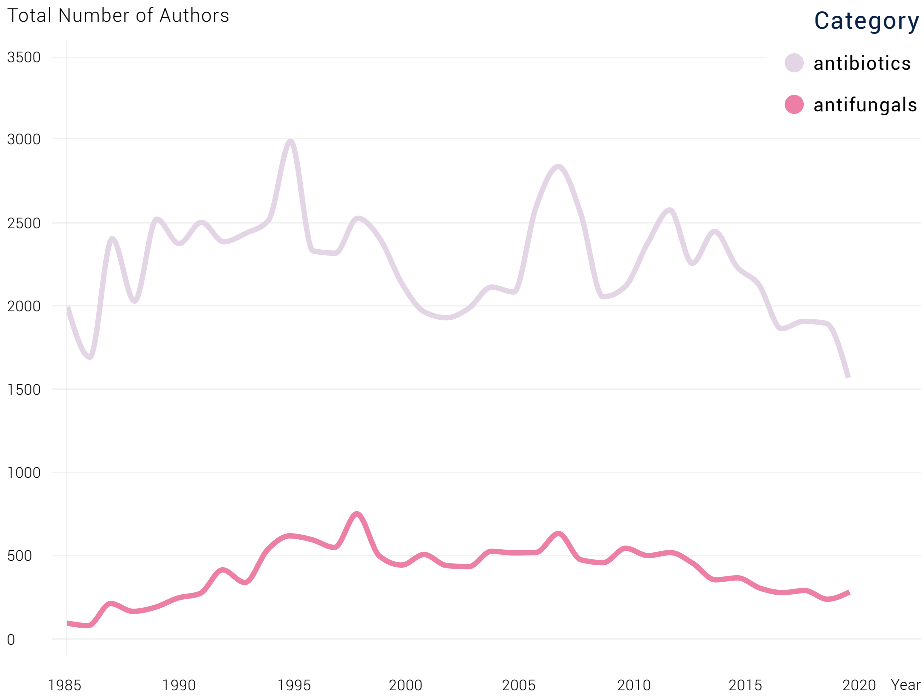


FIGURE 3. TOTAL NUMBER OF AMR AUTHORS HAS FALLEN BY ALMOST HALF SINCE 1995



AMR Research Output Has Fallen Behind Cancer and HIV/AIDS

The declines in AMR research talent and output stand in stark contrast to other disease areas, such as cancer and HIV/AIDS. These fields now dwarf AMR by almost every measure despite the clear public health importance of AMR.

For publications, there were 2,195 clinical trials and RCT papers published on cancer in 2022 – over 35 times the number of publications on priority bacteria (Figure 4). There were also approximately 5.5 times more publications on HIV/AIDS than these same bacteria, even as AMR is estimated to contribute to more deaths every year than AIDS.[8]

For patents, in 2022, there were approximately 20 times more patents awarded for cancer (2,388) than for antibiotics (115). HIV treatment patent numbers were closer to antibiotics and antifungals, but still higher in every year since 1992 (Figure 5).

This data, together with the evidence for publications, strongly supports ongoing reports that there is a decline in research activity in AMR. This data indicates less research is taking place, leading to fewer publications, low patent activity, and ultimately, fewer new drugs.

FIGURE 4. PUBLICATIONS ON CANCER AND HIV/AIDS FAR OUTSTRIP AMR TOPICS

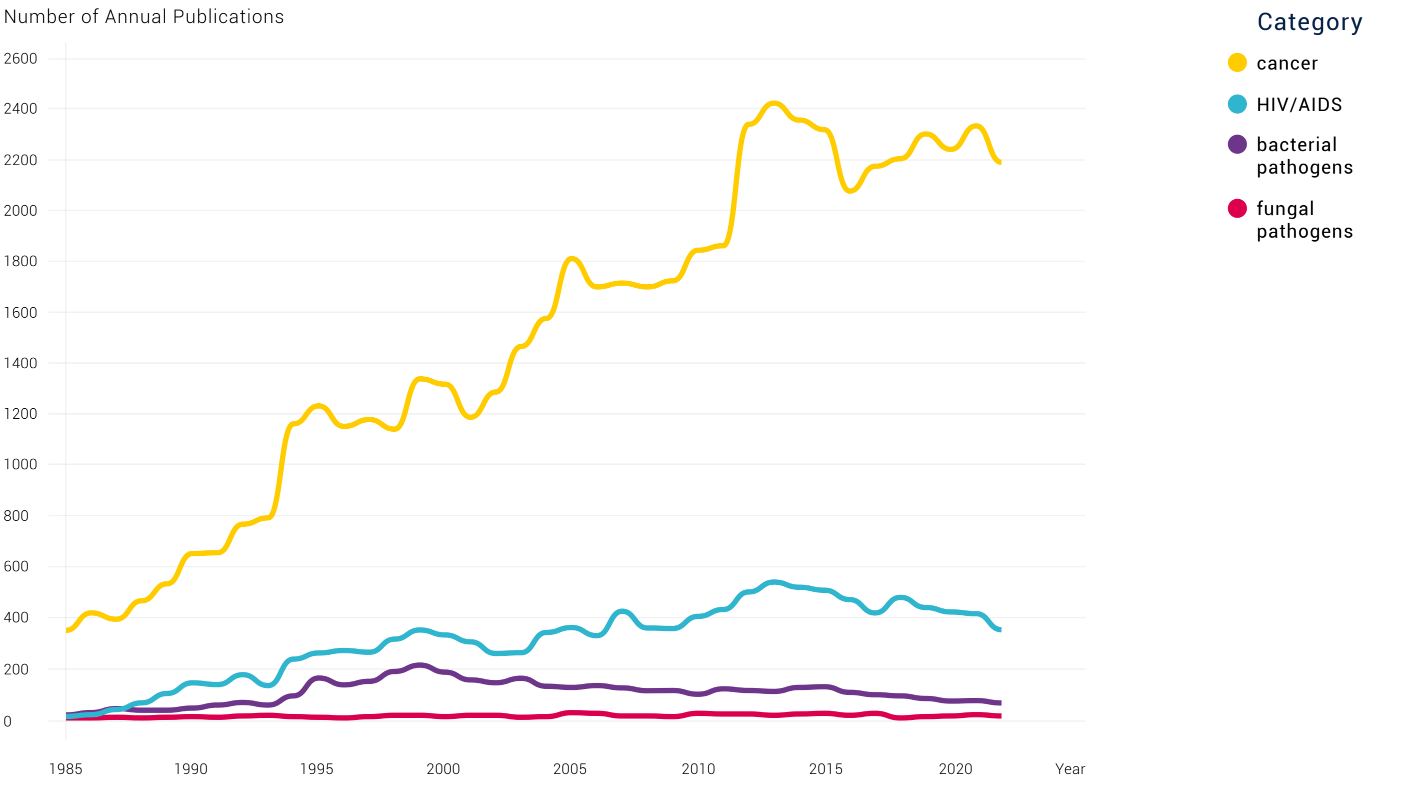
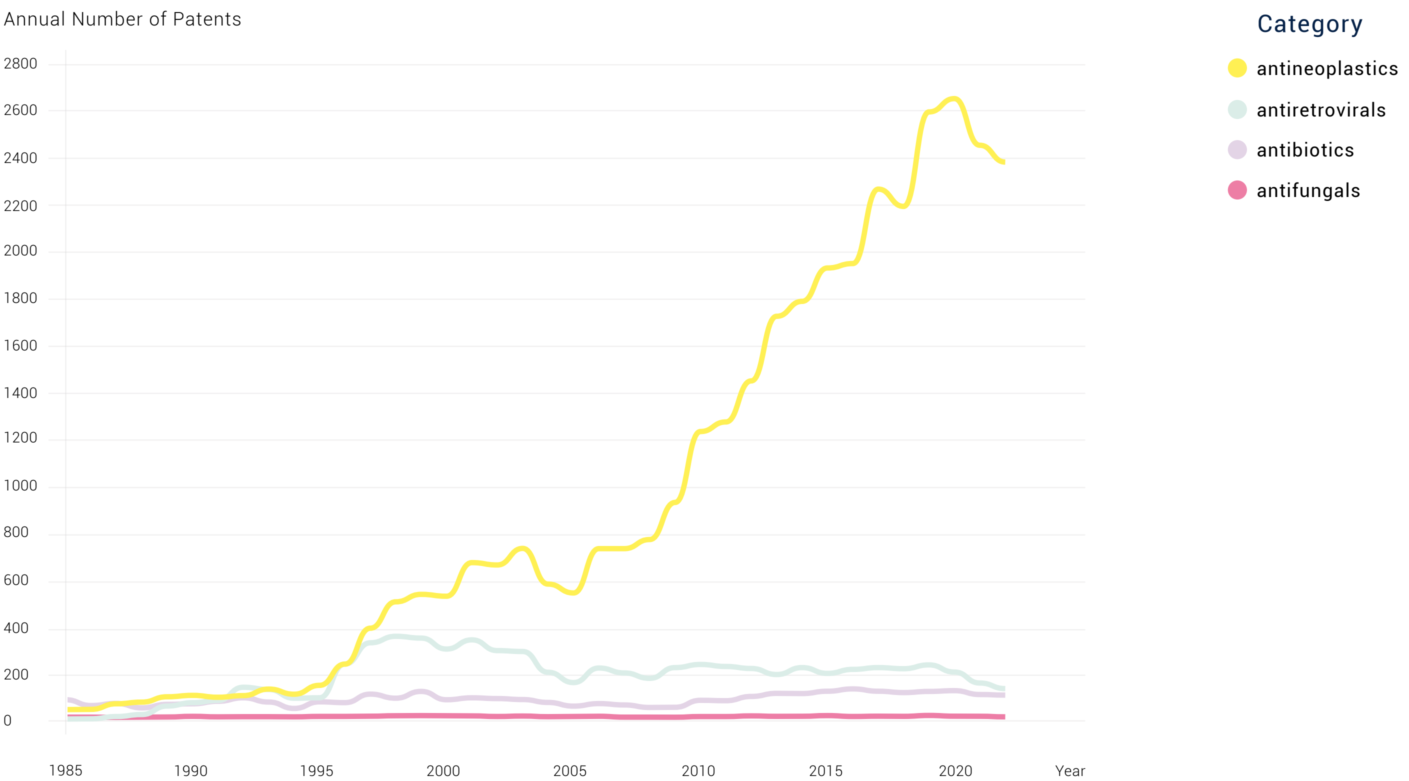


FIGURE 5. PATENTS FOR ANTINEOPLASTICS AND ANTIRETROVIRALS EXCEED ANTIBIOTICS AND ANTIFUNGALS



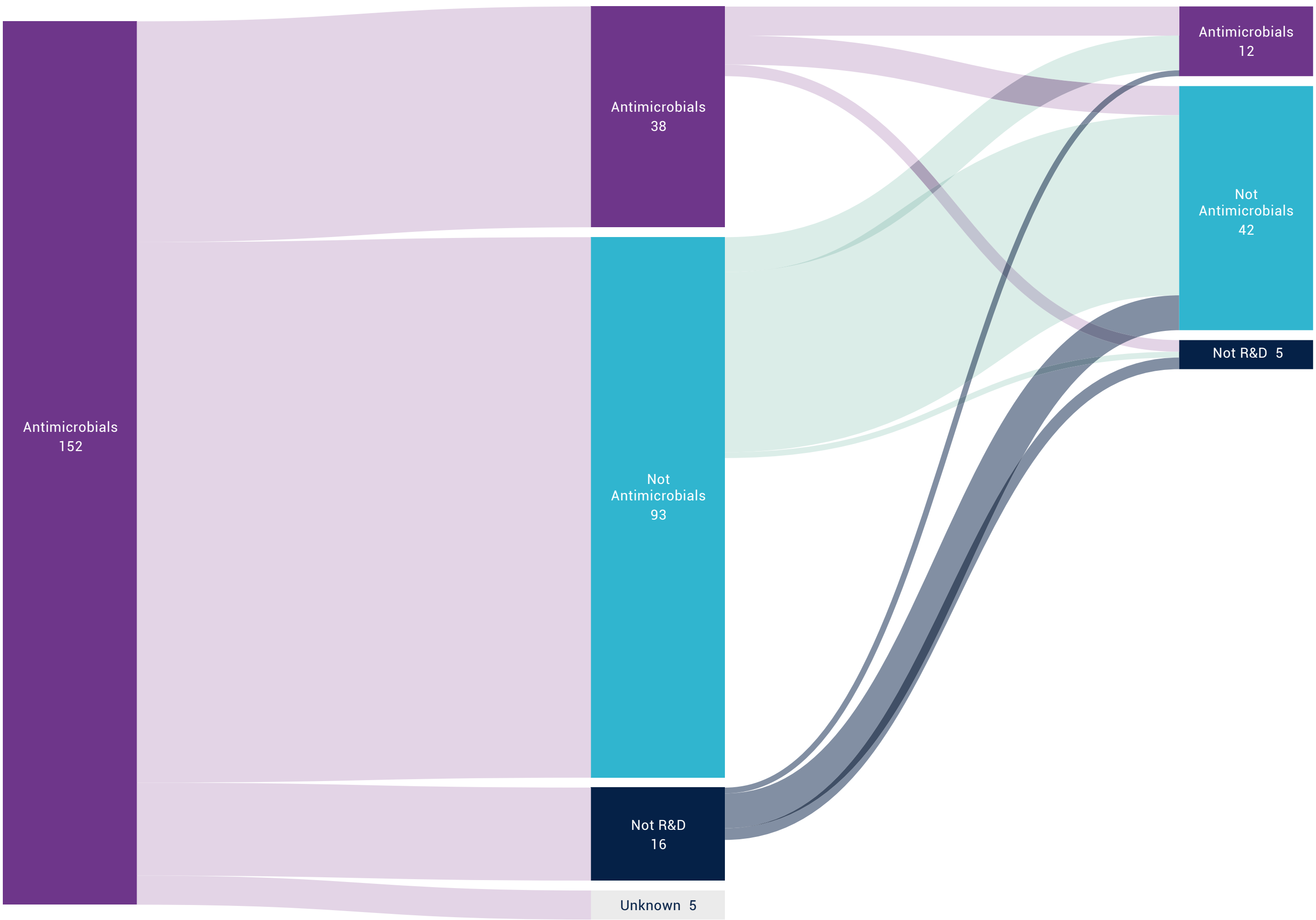
The AMR Field Is Losing the Talent Needed to Meet a Top Global Health Threat

Our analysis indicates that the pool of scientific talent in AMR is declining and trails other areas. Looking across data sources and estimates (see Appendix for full methodology), we estimate that approximately 3,000 AMR researchers are currently active in the world (given a range of 1,218 – 4,726). This compares with approximately 29,500 cancer / antineoplastics researchers (12,760 – 46,249) and 3,900 HIV/AIDS / antiretroviral researchers (2,406 – 5,371).

Source	Overview of AMR R&D Researcher Estimates	Applying Estimate Methods to Comparator Data	
		[Antineoplastics]	[Antiretrovirals]
2017 BCG Paper	Approx. 500		
AMR R&D Hub Data	818-8,278		
PUBMED Data + Patent Data – All researchers	2,014-3,546	15,822-49,311	3,029-5,994
PUBMED Data + Patent Data – All researchers with at least 3 publications in career	821-2,353	9,697-43,186	1,783-4,748

These high-level estimates are supported by a more granular review of career trajectories. Among ~150 people with public LinkedIn profiles who worked at companies that had previously funded but then abandoned AMR research, we found that most immediately left the field of antimicrobials after funding challenges arose; by their second job change, just 10% remained in the field (Figure 6).

FIGURE 6. CAREER PATHS AT SIX FIRMS WHO ABANDONED AMR-RELATED R&D



Researchers and experts in the AMR field remain interested, engaged, and passionate about their research. For this report, we interviewed many current and former experts in AMR-related R&D who expressed a strong passion for the field and the impact it has on patients. These scientists and researchers are the field's greatest strength and a critical resource for the future.

However, researchers also agreed that it is difficult to recruit and retain talent. Overall, a lack of investment, poor professional incentives, and declining employment opportunities are currently forcing AMR researchers to abandon their passion and leave the field.

Drivers

A Broken Market Constrains AMR Researchers

The Broken Pipeline Undermines Investment & Employment

Previous reports and studies frequently describe the "broken pipeline" for AMR-focused R&D.[9, 10, 11] In recent years, AstraZeneca, Novartis, and Johnson & Johnson have all exited or cut back their work on AMR, including closing R&D facilities, selling antimicrobial portfolios, ending AMR development, and letting go of research teams.[12, 13, 14, 15]

This leaves much of the work to small- and medium-sized enterprises (SMEs), which face severe cost pressures and the threat of bankruptcy. According to a recent report by the BEAM Alliance, 54% of their member SMEs don't even have enough funds to cover a year's worth of operations, and 33% have less than €200,000 cash.[16]

Faced with a broken market, companies struggle to recoup their investments in the drug research, discovery, and clinical trial phases, even when they do deliver a new antimicrobial therapy.[17] The case of Achaogen is a prime example. Even after securing approval for plazomicin, the company was still forced to declare bankruptcy in April 2019 – after spending nearly a billion dollars and 15 years developing the antibiotic.[4]

"

A critical challenge in the field of AMR is the insecure job market with the emergence and departure of so many biotechs."

Robert Skov

President-elect & Secretary General, ESCMID

> If I were entering the field today, I would not go into this line of work. My career has been wonderful, but this field is no longer thriving."
>
> AMR researcher

Private & Public Funding for AMR Trails Behind Other Areas

Given these struggles, it's no surprise that private and public funding for AMR is scarce. According to a 2022 report from the Biotechnology Innovation Organization (BIO), "The State of Innovation in Antibacterial Therapeutics," antimicrobial companies raised almost 17 times less funding than oncology companies across a range of different capital sources.[18]

Governments also commit less funding to AMR when compared with other disease areas. Even in a country like the United Kingdom, which is one of the world's largest investors in the fight against AMR, we see a disparity.[19] According to the NIH's Research, Condition, and Disease Categorization (RCDC) system database, $686 million was spent on AMR in FY 2022; in contrast, almost $3 billion was spent on HIV/AIDS.[20]

There Are Limited Incentives for Infectious Disease as a Medical Specialty

Clinicians are a crucial part of antimicrobial and antifungal R&D teams. Yet, in the countries where AMR-related R&D takes place, infectious disease specialist numbers are low, and new specialists are not entering the field due to a lack of incentives.[21]

> “
>
> Infectious disease specialists require two more years of training, and the average pay is lower than that of a hospitalist, for very similar work. If you want to do R&D, the situation is even worse. It's a huge ask."
>
> Dr. Dan Diekema
> Infectious Disease Specialist

In 2022, 44% of infectious disease fellowships went unfilled in the United States – more than double the proportion of unfilled fellowships across all specialties (21.7%).[22] Nearly 80% of U.S. counties either have below-average ID physician density or do not have ID physicians at all.[23] A 2022 Medscape report showed a pay gap of $4,000 between infectious disease doctors and internal medicine doctors across the United States, despite the additional years of training and debt required.[24]

Currently, the U.S. is not training enough ID researchers, including ID physician-scientists, who are critical to lead clinical trials for novel antimicrobial R&D as well as for basic science studies foundational for drug development. In 2022 alone, just above half of ID physician training slots were filled compared to other physician specialties that filled nearly all their programs.[25] The National Institute of Allergy and Infectious Diseases' (NIAID), despite having a higher total budget than several other NIH institutes, has invested in only 81,000 awards in 2022, a figure much less than compared to investments by other NIH institutes focused on other disease areas.[25] Infectious disease specialists provide the clinical knowledge needed to produce high-quality antimicrobial and antifungal R&D. Lower number of specialists harms the R&D sector and reflects the low levels of support for AMR across the society.

Overall, these trends lead to unsustainable conditions for the professionals and companies that are urgently needed to lead the response to AMR. As a result, researchers often have little choice and must exit the field.

Conclusion

Action Is Needed to Restore and Build a Robust AMR Research Workforce

As the AMR challenge grows more dire, the talent in the AMR field grows more important. It takes experience, time, and skill to build a high-quality team of researchers, including lab technicians, research assistants, post-doctoral researchers, and principal investigators.

Yet it is becoming increasingly difficult to build such a team. Many experts with essential knowledge have already exited the field, and those who remain face cost pressures, limited incentives, and a lack of compelling job, career, and research opportunities. The AMR brain drain phenomenon may complicate every part of the drug development process, from basic discovery research through clinical testing all the way up to regulatory approval as robust expertise is needed within agencies like FDA and EMA to ensure judicious safety and efficacy reviews of all new antimicrobials.

Thankfully, societies are increasingly discussing how to address the enduring threat of AMR. We need to bring greater urgency to these discussions and consider the essential role of R&D professionals. Ensuring that we have a workforce of trained research personnel will do much to help research funding go as far as possible and yield the most successful results to tackle AMR.

Several actions and steps point a way forward:

Adequate funding for push and pull incentives can play a key role to address low funding. Incentives are required not just to support the R&D pipeline, but to ensure that we can slow down and halt the outflow of key talent in this space. There are organizations like CARB-X that are currently supporting several dozen small companies, giving them and their researchers a lifeline. These efforts should be further encouraged. If we are to meet the need for new antimicrobials, then we must invest in the people who are responsible for their discovery.

Ongoing efforts in the field provide a starting point and potential catalyst. There are several companies conducting R&D in new antimicrobials, and organizations such as ICARe[26] and Future Leaders Against AMR[27] are leading the way for early career researchers to gain experience in AMR research. These efforts underscore the important work being done to train scientists to conduct new, groundbreaking AMR research.

New initiatives can tap into the passion and commitment of researchers, scientists, and specialists. Infectious disease doctors say they enter the field because of the opportunity to work across different specialties, work in a variety of settings, and because of the intellectual stimulation of infectious disease problem solving.[28] Research has found that the majority of ID specialists felt they had accomplished something meaningful in their work and found it rewarding.[29] However, new investments are needed to help more physicians overcome the financial barriers to entering ID, namely high medical student debt, and inadequate compensation relative to general internists and other medical specialists. The US enacted the Bio-Preparedness Workforce Pilot Program to provide targeted loan repayment to ID clinicians, but must now fund this program, in addition to improving ID physician reimbursement and increasing federal funding for early career ID physician-scientists.

The decline in the size of the R&D workforce adds urgency to the already well-recognized need for greater investment in AMR. Together, global health organizations, governments, the private sector, and other stakeholders must come together to restore, build, and invest in the scientific talent that can match the scale and speed of the growing AMR crisis.

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Appendix

Methodology

This report collects and analyzes data from several data sources.

Publication and Publication Author Data

Data on publications was pulled from PUBMED. Only clinical trial and randomized control trial papers were used for this analysis. All publication searches were limited to papers published between January 1, 1985 and December 31, 2022.

Publications on infectious diseases and cancer were found by searching for pathogens listed in the WHO Priority Pathogen List and Fungal Priority Pathogen List. Specifically:

- For bacterial pathogens, this report searched for publications with the following terms in their title: Acinetobacter baumannii, Pseudomonas aeruginosa, Enterobacteriaceae, Enterococcus faecium, Staphylococcus aureus, Helicobacter pylori, Campylobacter, Salmonellae, Neisseria gonorrhoeae, Streptococcus pneumoniae, Haemophilus influenzae, Shigella.

- For fungal pathogens, this report searched for publications with the following terms in their title: Cryptococcus neoformans, Nakaseomyces glabrata, Scedosporium, Candida auris, Histoplasma, Lomentospora prolificans, Aspergillus fumigatus, Eumycetoma, Coccidioides , Candida albicans, Mucorales, Pichia kudriavzevii, Fusarium, Cryptococcus gattii, Candida tropicalis, Talaromyces marneffei, Candida parapsilosis, Pneumocystis jirovecii, Paracoccidioides

- For HIV/AIDS, this report searched for publications with the following terms in their title: HIV, AIDS

- For cancer, this report searched for publications with the following terms in their title: cancer, malignant neoplasm, malignant tumor, malignancy, metastatic tumor, metastatic neoplasm

Publications on drugs were found by searching by generic drug name.

Specifically:

- For antibiotics, this report searched for publications with the following terms in their title: AND Amikacin, Amoxicillin, Amoxicillin/clavulanic-acid, Ampicillin, Ampicillin/sulbactam, Arbekacin, Aspoxicillin, Azidocillin, Azithromycin, Azlocillin, Aztreonam, Bacampicillin, Bekanamycin, Benzathine-benzylpenicillin, Benzylpenicillin, Biapenem, Brodimoprim, Carbenicillin, Carindacillin, Carumonam, Cefacetrile, Cefaclor, Cefadroxil, Cefalexin, Cefaloridine, Cefalotin, Cefamandole, Cefapirin, Cefatrizine, Cefazedone, Cefazolin, Cefbuperazone, Cefcapene-pivoxil, Cefdinir, Cefditoren-pivoxil, Cefepime, Cefetamet-pivoxil, Cefiderocol, Cefixime, Cefmenoxime, Cefmetazole, Cefminox, Cefodizime, Cefonicid, Cefoperazone, Ceforanide, Cefoselis, Cefotaxime, Cefotetan, Cefotiam, Cefoxitin, Cefozopran, Cefpiramide, Cefpirome, Cefpodoxime-proxetil, Cefprozil, Cefradine, Cefroxadine, Cefsulodin, Ceftaroline-fosamil, Ceftazidime, Ceftazidime/avibactam, Cefteram-pivoxil, Ceftezole, Ceftibuten, Ceftizoxime, Ceftobiprole-medocaril, Ceftolozane/tazobactam, Ceftriaxone, Cefuroxime, Chloramphenicol, Chlortetracycline, Cinoxacin, Ciprofloxacin, Clarithromycin, Clindamycin, Clofoctol, Clometocillin, Clomocycline, Cloxacillin, Colistin, Colistin, Dalbavancin, Dalfopristin/quinupristin, Daptomycin, Delafloxacin, Demeclocycline, Dibekacin, Dicloxacillin, Dirithromycin, Doripenem, Doxycycline, Enoxacin, Epicillin, Eravacycline, Ertapenem, Erythromycin, Faropenem, Fidaxomicin, Fleroxacin, Flomoxef, Flucloxacillin, Flumequine, Flurithromycin, Fosfomycin, Fosfomycin, Furazidin, Fusidic-acid, Garenoxacin, Gatifloxacin, Gemifloxacin, Gentamicin, Grepafloxacin, Hetacillin, Iclaprim, Imipenem/cilastatin, Imipenem/cilastatin/relebactam, Isepamicin, Josamycin, Kanamycin, Kanamycin, Lascufloxacin, Latamoxef, Lefamulin, Levofloxacin, Levonadifloxacin, Lincomycin, Linezolid, Lomefloxacin, Loracarbef, Lymecycline, Mecillinam, Meropenem, Meropenem/vaborbactam, Metacycline, Metampicillin, Meticillin, Metronidazole, Metronidazole, Mezlocillin, Micronomicin, Midecamycin, Minocycline, Minocycline, Miocamycin, Moxifloxacin, Nafcillin, Nemonoxacin, Neomycin, Neomycin, Netilmicin, Nifurtoinol, Nitrofurantoin, Norfloxacin, Ofloxacin, Oleandomycin, Omadacycline, Oritavancin, Ornidazole, Ornidazole, Oxacillin, Oxolinic-acid, Oxytetracycline, Panipenem, Pazufloxacin, Pefloxacin, Penamecillin, Penimepicycline, Pheneticillin, Phenoxymethylpenicillin, Pipemidic-acid, Piperacillin, Piperacillin/tazobactam, Piromidic-acid, Pivampicillin, Pivmecillinam, Plazomicin, Polymyxin-B, Polymyxin-B, Pristinamycin, Procaine-benzylpenicillin, Propicillin, Prulifloxacin, Ribostamycin, Rifabutin, Rifampicin, Rifamycin, Rifamycin, Rifaximin, Rokitamycin, Rolitetracycline, Rosoxacin, Roxithromycin, Rufloxacin, Sarecycline, Secnidazole, Sisomicin, Sitafloxacin, Solithromycin, Sparfloxacin, Spectinomycin, Spiramycin, Streptoduocin, Streptomycin, Streptomycin, Sulbactam, Sulbenicillin, Sulfadiazine , Sulfadiazine/tetroxoprim, Sulfadiazine/trimethoprim, Sulfadimethoxine, Sulfadimidine, Sulfafurazole, Sulfaisodimidine, Sulfalene, Sulfamazone, Sulfamerazine, Sulfamerazine/trimethoprim, Sulfamethizole, Sulfamethoxazole , Sulfamethoxazole/trimethoprim, Sulfamethoxypyridazine, Sulfametomidine, Sulfametoxydiazine, Sulfametrole/trimethoprim, Sulfamoxole , Sulfamoxole/trimethoprim, Sulfanilamide, Sulfaperin, Sulfaphenazole, Sulfapyridine, Sulfathiazole, Sulfathiourea, Sultamicillin, Talampicillin, Tazobactam, Tebipenem, Tedizolid, Teicoplanin, Telavancin, Telithromycin, Temafloxacin, Temocillin, Tetracycline, Thiamphenicol, Ticarcillin, Tigecycline, Tinidazole, Tinidazole, Tobramycin, Tosufloxacin, Trimethoprim, Troleandomycin, Trovafloxacin, Vancomycin, Vancomycin

- **For antifungals**, this report searched for publications with the following terms in their title: Oteseconazole, Rezafungin, Amphotericin B, Anidulafungin, Caspofungin, Fluconazole, Flucytosine, Ibrexafungerp, Isavuconazonium sulfate, Itraconazole, Ketoconazole, Micafungin, Nystatin, Posaconazole, Terbinafine, Voriconazole

- **For antiretrovirals**, this report searched for all publications assigned the MeSH term of "Anti-Retroviral Agents." This search was not felt to be comprehensive, so it was supplemented by a search for publications with the following terms in their title: abacavir, atazanavir, cabotegravir, cobicistat, darunavir, dolutegravir, doravirine, efavirenz, emtricitabine, enfuvirtide, etravirine, fosamprenavir, fostemsavir, ibalizumab-uiyk, lamivudine, lenacapavir, maraviroc, nevirapine, raltegravir, rilpivirine, ritonavir, tenofovir disoproxil, tipranavir, zidovudine

- **For antineoplastics**, this report searched for all publications assigned the MeSH term of "Antineoplastic Agents."

Author information was collected by downloading the CSV summary data from PUBMED for each publication. This data is organized into rows by publication with all author names in a single cell per publication. To count the number of authors per publication, these cells were expanded into a dataset with one row per author, year of publication, publication ID, and publication category (antibiotic, antifungal, antineoplastic, antiretroviral, bacterial pathogen, fungal pathogen, cancer, HIV). By sorting these rows by category, year, and author, it was possible to count publications temporally, and then to assign a flag to each author denoting their number of publications per category. Charts were then created by tracking distinct publication ID or author numbers by year, category, and number of total publications.

Patent Data

Patent Data was downloaded from PatentsView, a website developed by the Office of the Chief Economist at the U.S. Patent & Trademark Office (USPTO) to disseminate patent data. The g_patent dataset containing 8,517,464 patents was used for this report. Patents were pulled from this dataset and assigned categories as follows:

- **Antibiotics:** Patents were required to contain the terms "antibiotic" or "antimicrobial" in their title or abstract.

- **Antifungals:** Patents were required to contain the terms "antifungal" in their title or abstract.

- **Antineoplastics:** Patents were required to contain the terms "cancer" or "antineoplastic" in their title or abstract.

- **Antiretroviral:** Patents were required to contain the terms "HIV," "AIDS," or "antiretroviral" in their title or abstract.

Upon examination of the data, it was found that the antibiotics category contained many non-relevant records. Thus, patents with the following terms in their title or abstract were excluded: feed, agriculture, sanitizer, cleaning, surface, test, device, plastic, wipe, tissue, polymer, adhesive.

Research Project Data

Data on research projects was collected from the dynamic dashboard of the Global AMR R&D Hub. Information on all recorded projects was first downloaded from the Hub. Upon the advice of Hub staff, only data from 2020 and prior was considered complete and used for this analysis.

Researcher Number Estimation Methods

Author counts from PUBMED were calculated by taking the largest annual author number from what was considered to be the last three years of complete author data: 2018-2020. This number was calculated for all authors, and for authors with at least three publications in their career. Patent numbers were added to those publication numbers. To calculate patent numbers, this report assumed that the average number of researchers supporting a patent would be equivalent to range stretching from one to the most recent average number of researchers supporting each category of publication (for antimicrobials, this is equivalent to 10.12 researchers in 2020; antineoplastics: 13.59; antiretrovirals: 13.20). This range was added to the author numbers pulled from publication data to achieve a final set of ranges. An estimate was also created based on the Global AMR R&D Hub Data for antimicrobials. Searching for projects under the “therapeutic” and “basic, therapeutic” research area categories and the “Human” sector subcategory, this report found 818 projects with start and end years completely or partially covering 2020. This number was multiplied by the most recent average number of researchers supporting publications in each drug category as of 2020 to achieve a range around the number of researchers supporting each project.

Once ranges were developed for each drug category, lower bounds and upper bounds were averaged to create an averaged ranged estimate.

LinkedIn Data

LinkedIn Data was collected by individually visiting the publicly available profiles of people working at six small antimicrobial development companies that have been found to have financial troubles in recent years. The following data points were recorded related to the person in question and their time at each of the six included companies and up to two job changes: Company Name, Drug development category, Name, Sex, Age, Advanced Degree 1 if applicable, Name of degree-granting institution, Location of degree-granting institution, Advanced Degree 2 if applicable, Name of degree-granting institution, Location of degree-granting institution, employment status, any work history after working at company, Start date year, End date year, City of company, Country of company.

This report aimed to capture people working in R&D specifically. In cases where it was unclear whether the person worked in R&D or not, they were included in this analysis.

ABOUT THE AMR INDUSTRY ALLIANCE

The AMR Industry Alliance is one of the largest private-sector coalitions established to provide sustainable solutions to curb antimicrobial resistance. The Alliance, comprised of 77 biotechnology, diagnostics, generics, and research-based pharmaceutical companies and 10 trade associations, facilitates collaboration, reports on the industry's contribution to the fight against AMR, and engages with external stakeholders. The Alliance seeks to contribute sustainable solutions to curb antimicrobial resistance by creating broad industry momentum and facilitating collaboration between the public and private sectors.

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