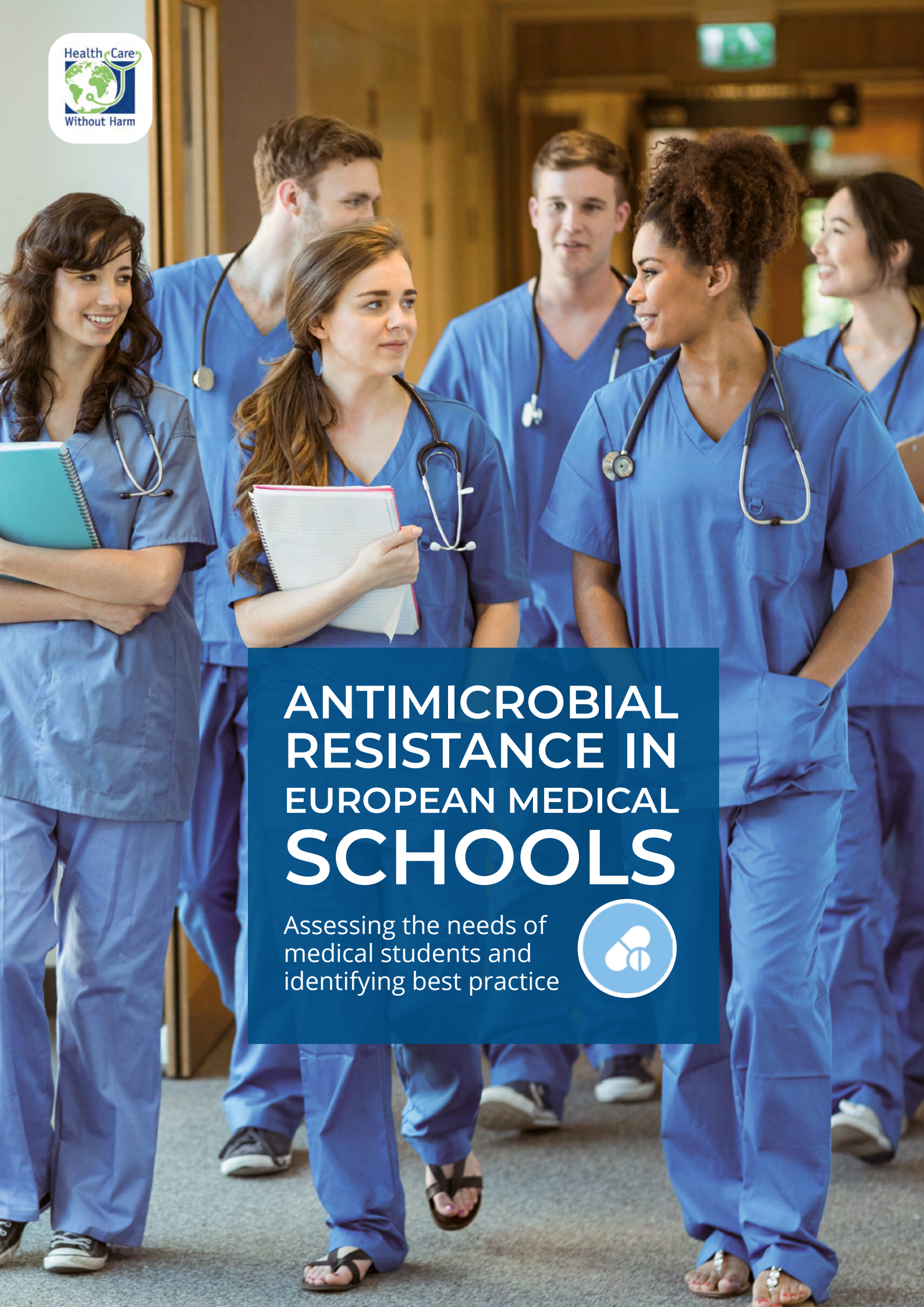


Health Care Without Harm

ANTIMICROBIAL RESISTANCE IN EUROPEAN MEDICAL SCHOOLS

Assessing the needs of medical students and identifying best practice

INTRODUCTION

Antimicrobial resistance (AMR) is a major threat to global health – without effective antimicrobials, common infections that we can currently treat effectively will once again become fatal; procedures such as cancer chemotherapy, diabetes management, major surgery, or organ transplantation would put patients at risk.

In the EU, AMR is annually responsible for an estimated 33,000 deaths and more than €1.5bn in healthcare costs and productivity losses.[1] The burden of antibiotic-resistant infections in Europe is comparable to that of HIV/AIDS, influenza, and tuberculosis combined.[2] If no effective action is taken, AMR could cause 390,000 deaths per year in Europe by 2050.[3]

Whilst antimicrobial resistance is a natural process, the misuse and overuse of antimicrobials is dangerously accelerating its development.[4] Studies have shown a strong correlation between levels of antibiotic use and levels of resistance.[5] It is therefore crucial to address inappropriate use and overuse of antibiotics to slow down the development of AMR.[6]

Another contributing factor in resistance is antibiotics entering the environment throughout their life cycle: manufacturing discharges, excretion during use, and improper disposal; up to 80% are excreted through urine and faeces.[7] They can then pollute the environment, exert selective pressure that increases the prevalence of resistance, and act as a driver for the development of new resistance in pathogenic bacteria.[8]

According to the OECD, up to 50% of antimicrobials used in human healthcare may be inappropriate, notably because of inappropriate prescription of antimicrobials due to cognitive biases.[9,10] Education is therefore key to influencing prescribing behaviour and optimising antimicrobial use in the healthcare sector.[11]

Medical students are the future of the medical profession – educating them about rational prescribing practices should be a key component of any comprehensive strategy to tackle AMR. There is therefore a crucial need to develop medical curricula that comprehensively address the core principles of antimicrobial stewardship.[12]

The Global Action Plan on AMR, adopted in 2015 by the WHO's World Health Assembly, highlights the importance of education in ensuring understanding and awareness amongst professionals, whilst the EU One Health Action Plan against AMR states that the EU should support Member States in improving professional understanding of AMR and support more informed clinical decision-making and appropriate prescribing.[13,14]

Several studies have identified a lack of confidence and knowledge gaps on antibiotic prescribing among medical students and have pointed out a need for further education.[10] Whilst many AMR-related initiatives have targeted hospitals and medical doctors, very few have been aimed at medical students despite gaps in medical curricula.[6]

This report launched by Health Care Without Harm (HCWH) Europe contributes to enhancing AMR education in medical schools in Europe; increasing awareness on AMR among future medical doctors, curbing inappropriate antimicrobial prescriptions, and reducing the amount of antimicrobial residues in the environment and exposure to AMR.

In this report, we have assessed medical students' educational needs in relation to AMR – this is based on a survey completed by fourth-year to sixth-year students in medical schools across Europe. We have used these survey results and selected case studies of best practice from six universities as the basis for our recommendations to update medical school curricula.

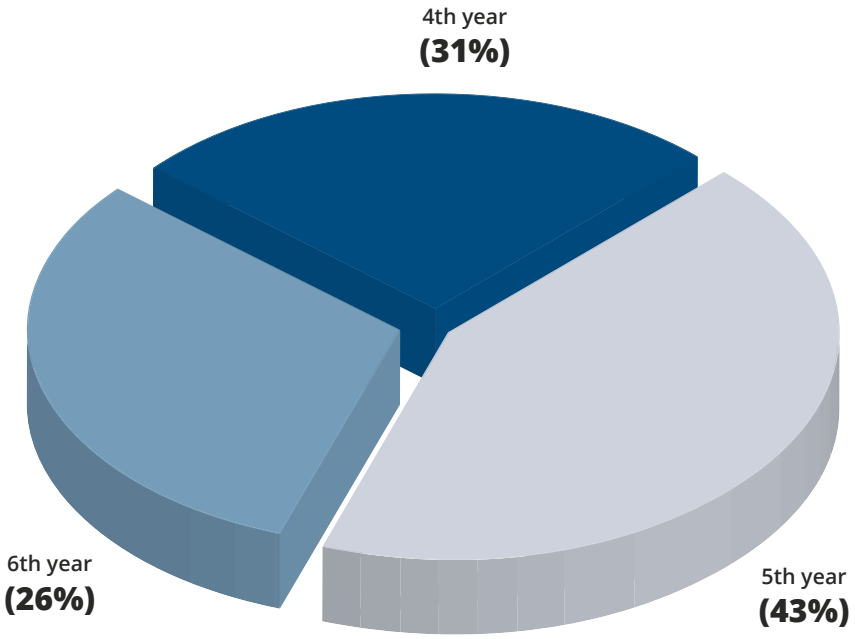
WHAT ARE THE GAPS IN AMR EDUCATION IN EUROPEAN MEDICAL SCHOOLS?

In 2020, HCWH Europe launched a survey to assess the educational needs of fourth-year to sixth-year students studying in a medical school in Europe. It was designed based on a literature review and its content was discussed with medical students. The survey and its resulting analytics are available on our website.

This survey was disseminated through our Europe-wide network of healthcare providers and organisations; we would also like to thank associations of medical students who supported in sharing this survey, in particular the International Federation of Medical Students' Associations (IFMSA) and the European Medical Students' Association (EMSA).

Between March-June 2020, we received responses from 357 medical students studying at 83 medical schools or universities across 28 countries of the WHO European Region. The majority of students were in their fifth year of study and were currently undertaking or had previously been on a hospital rotation/clinical training.

Survey participants' year of study



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Geographical spread of survey responses

<3 replies
Austria, Estonia, Georgia, Serbia, Switzerland, Turkey, Ukraine

3-5 replies
Finland, France, Greece, Ireland, Latvia, the Netherlands, the United Kingdom

6-10 replies
Azerbaijan, Belgium, Germany, Portugal

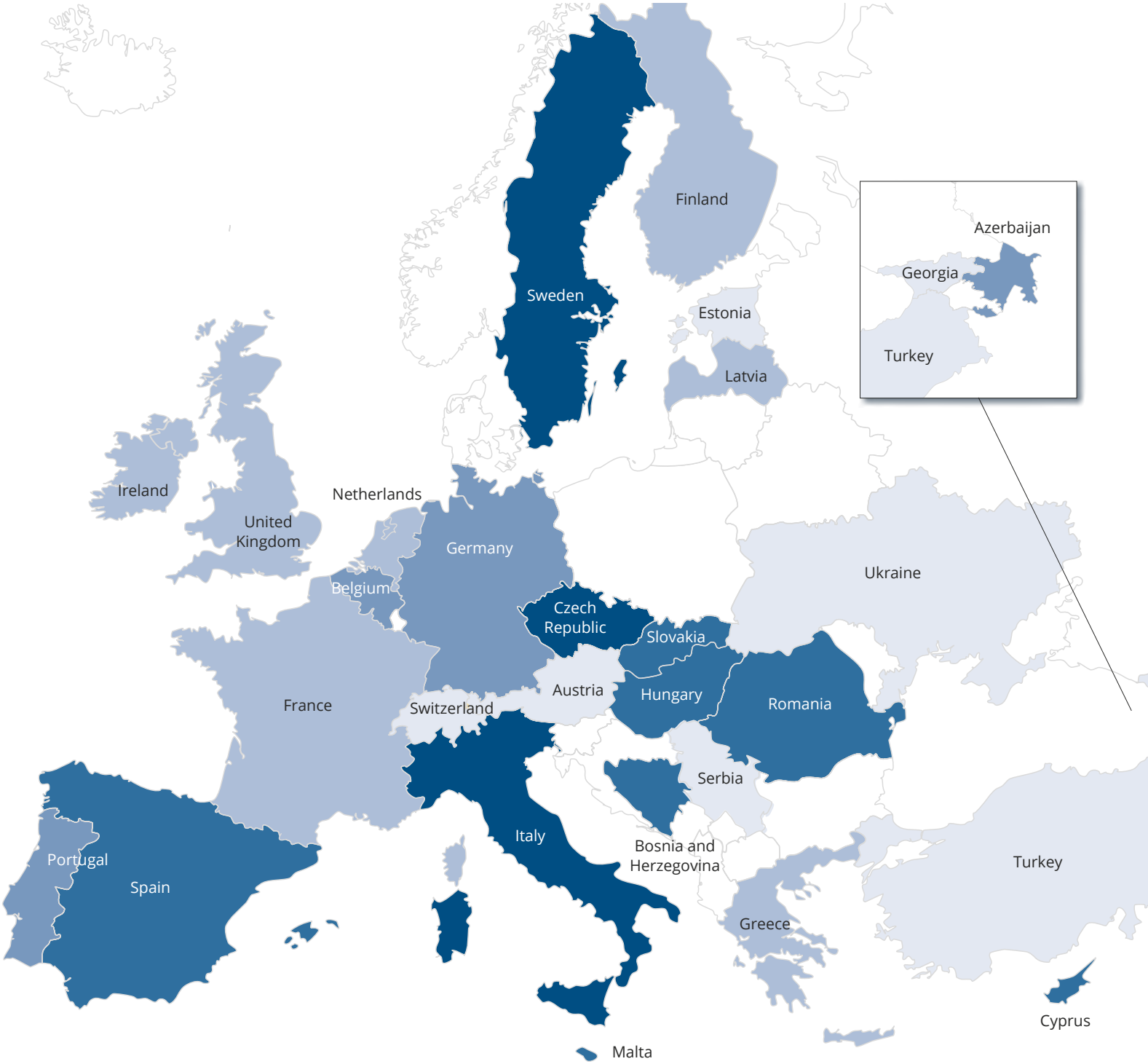
11-20 replies
Bosnia and Herzegovina, Cyprus, Hungary, Malta, Romania, Slovakia, Spain

20< replies
The Czech Republic, Italy, Sweden

The results are divided into three sections centred on the following questions:

1. **How important is AMR for respondents and what role do they see for medical doctors?**
2. **How is AMR integrated into their medical curriculum and during their hospital rotation?**
3. **What do they think of their education on antimicrobial prescribing?**

With this survey we do not claim to comprehensively capture the views of the medical student community in Europe, as experiences and opinions will vary between countries, regions, and even between medical schools. This survey rather provides general insight from a large pool of students from across Europe on the importance of AMR education and on common gaps. The results, however, also need to be balanced in view of the wide variation in the number of respondents between countries, with a larger response from the Czech Republic, Sweden, and to a lesser extent, Italy.



WHO European Region

List of medical schools and universities of survey respondents

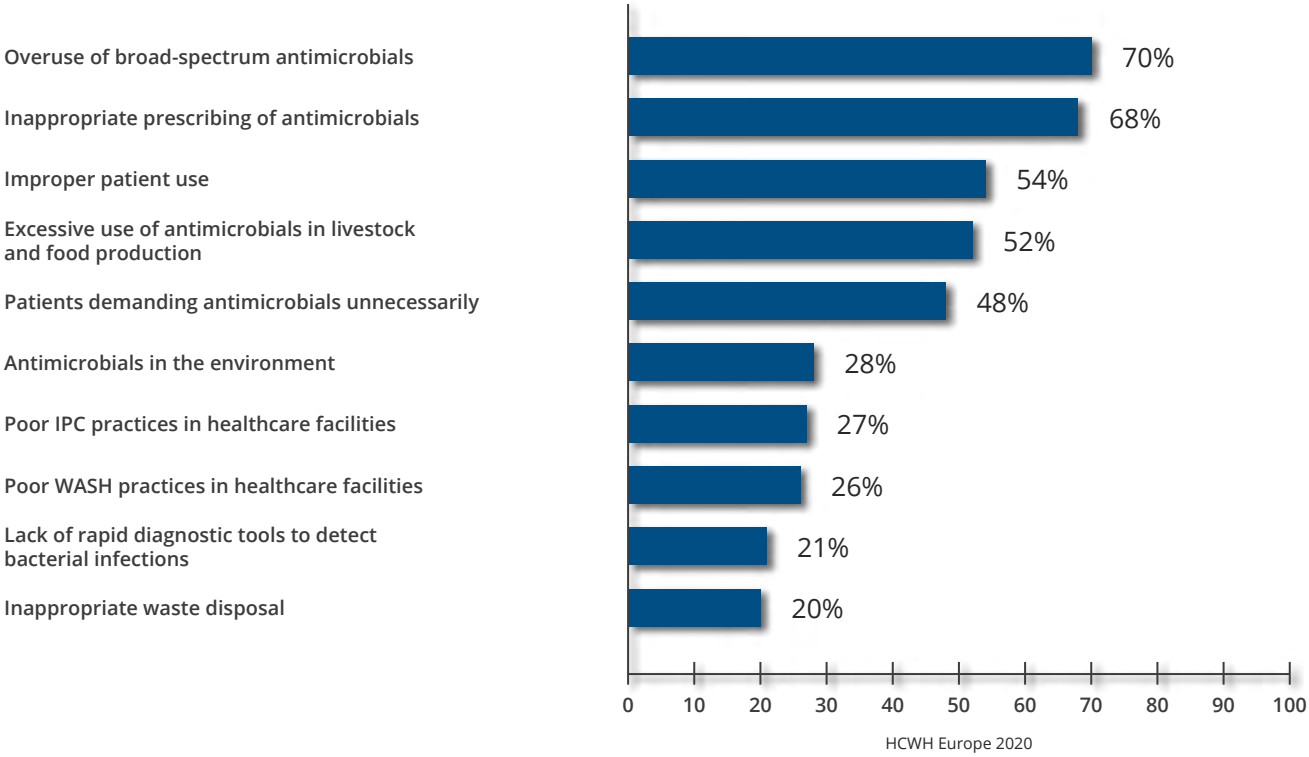
- Abel Salazar Biomedical Sciences Institute (ICBAS)
- Adnan Menderes University
- Aristotle University of Thessaloniki
- Autonomous University of Barcelona
- Azerbaijan Medical University
- Batumi Shota Rustaveli State University
- Carol Davila University of Medicine and Pharmacy
- Catholic University of Louvain (KU Leuven)
- Catholic University of Louvain (UCLouvain)
- Charité Universitätsmedizin Berlin
- Charles University, Faculty of Medicine in Pilsen
- Charles University, First Faculty of Medicine
- Charles University, Second Faculty of Medicine
- Charles University, Third Faculty of Medicine
- Danylo Halytsky Lviv National Medical University
- David Tvildiani Medical University
- Dunarea de Jos University of Galati
- Free University of Brussels (ULB)
- Friedrich-Alexander University Erlangen-Nürnberg
- Ghent University
- Grigore T. Popa University of Medicine and Pharmacy
- Humanitas University
- Iuliu Hatieganu University of Medicine and Pharmacy
- King's College London
- Lancaster University
- Leipzig University
- Magna Græcia University of Catanzaro
- Medical University of Graz
- NOVA Medical School
- Palacký University Olomouc
- Paul Sabatier University
- Pompeu Fabra University
- Radboud University
- Riga Stradins University
- Royal College of Surgeons in Ireland (RCSI)
- Ruhr-University Bochum
- Slovak Medical University in Bratislava (SMU)
- Tampere University
- Tor Vergata University of Rome
- Trinity College Dublin
- University of Bari Aldo Moro
- University of Beira Interior
- University of Belgrade
- University of Brescia
- University of Cambridge
- University of Campania Luigi Vanvitelli
- University of Catania
- University of Crete
- University of Cyprus
- University of Debrecen
- University of Eastern Piedmont
- University of Florence
- University of Helsinki
- University of Lausanne
- University of Liège
- University of Lisbon
- University of Lleida
- University of Lübeck
- University of Malta
- University of Medicine and Pharmacy of Craiova
- University of Milano-Bicocca
- University of Molise
- University of Mostar
- University of Oradea
- University of Oulu
- University of Padua
- University of Palermo
- University of Pisa
- University of Porto
- University of Rostock
- University of Rouen
- University of Sarajevo
- University of Sheffield
- University of Tartu
- University of Thessaly
- University of Trieste
- University of Turin
- University of Turku
- University of Tuzla
- University of Verona
- Uppsala University
- Victor Babeş University of Medicine and Pharmacy
- VU University Medical Center (VUmc)

The importance of AMR and the role of medical doctors

The survey respondents showed a high concern about AMR – over 90% considered AMR a very important global issue and close to 90% believed that AMR is either a very or moderately important issue in their country of study. Almost all participants (99%) agreed that AMR would be an increasingly serious issue in the future.

Over half of the medical students surveyed identified the overuse of broad-spectrum antimicrobials and inappropriate prescribing of antimicrobials as very important drivers of AMR in Europe. This correlates with the majority identifying medical doctors as best placed to address this problem, mainly by informing patients about proper use and through appropriate antimicrobial prescribing.

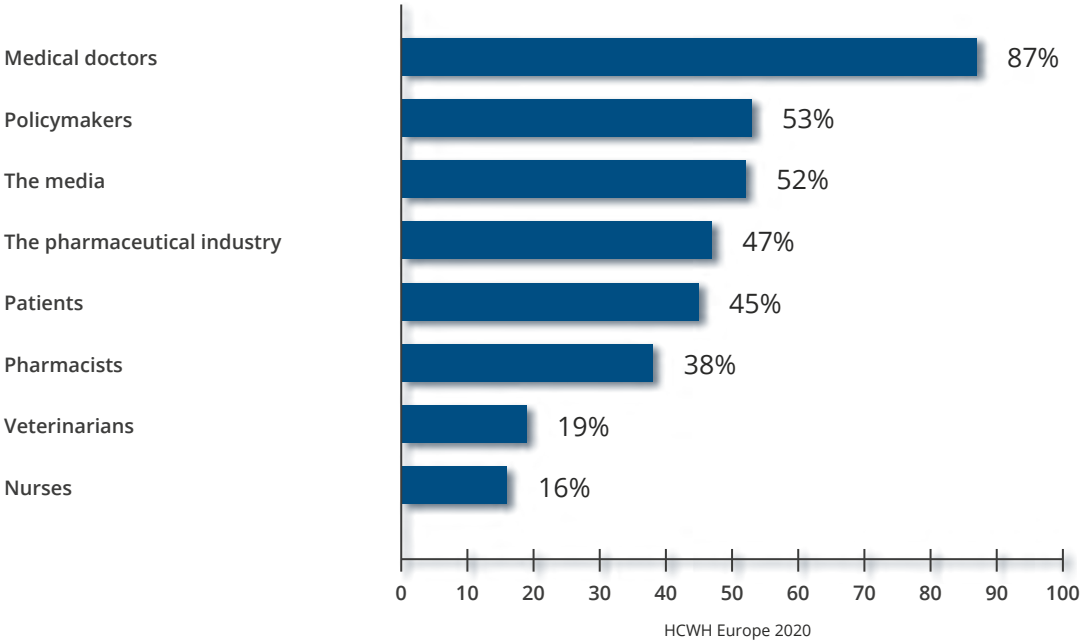
Which of these situations do you think are very important drivers of AMR in Europe? (multiple answers were allowed)



This is consistent with the findings from a recent ECDC survey report on healthcare workers in the EU/EEA, which reported that 90% of responding prescribers agreed or strongly agreed that they personally have a key role to play in helping control antibiotic resistance and that they consider antibiotic resistance when treating a patient.[15]

Improper patient use (e.g. not completing a treatment or self-medication) and patients demanding antimicrobials unnecessarily were also identified as very important drivers of AMR by approximately half of respondents. Taking this into account, it is interesting to note that only a minority considered pharmacists and nurses to be best placed to take action on AMR.

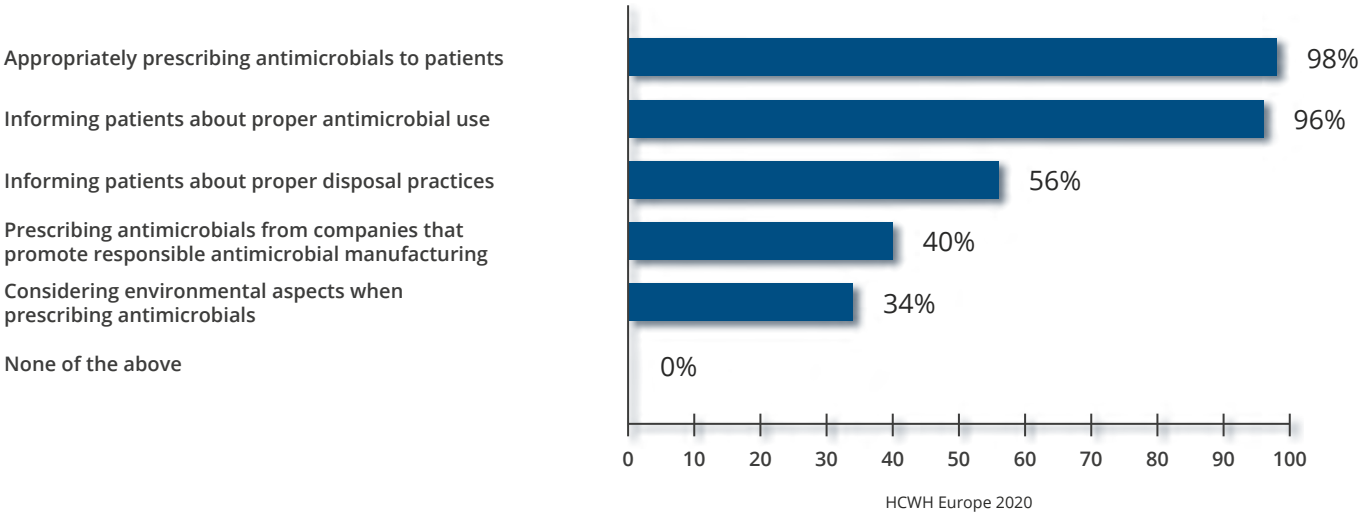
Who do you think are the best placed to tackle the development of AMR? (multiple answers were allowed)



Similarly, although more than half of respondents considered the excessive use of antimicrobials in livestock and food production to be an important cause of AMR, fewer than 20% felt that veterinarians are best placed to address AMR.

Only a quarter of respondents recognised that antimicrobials in the environment and inappropriate waste disposal practices have a very important impact on AMR, but more than 50% of the students believed that medical doctors have a role to play in informing patients about proper disposal practices. All respondents believed that medical doctors have a role in combatting AMR.

In which of the following situations do you think that medical doctors have a role to play? (multiple answers were allowed)



Whilst over 80% of respondents were concerned/very concerned by the ability of healthcare facilities to respond to AMR in the future – the lack of rapid diagnostic tools, poor infection prevention and control (IPC) practices, and poor WASH (water, sanitation, and hygiene) practices in healthcare facilities were not particularly considered as important drivers of AMR in Europe.

AMR in medical curricula and during hospital rotations

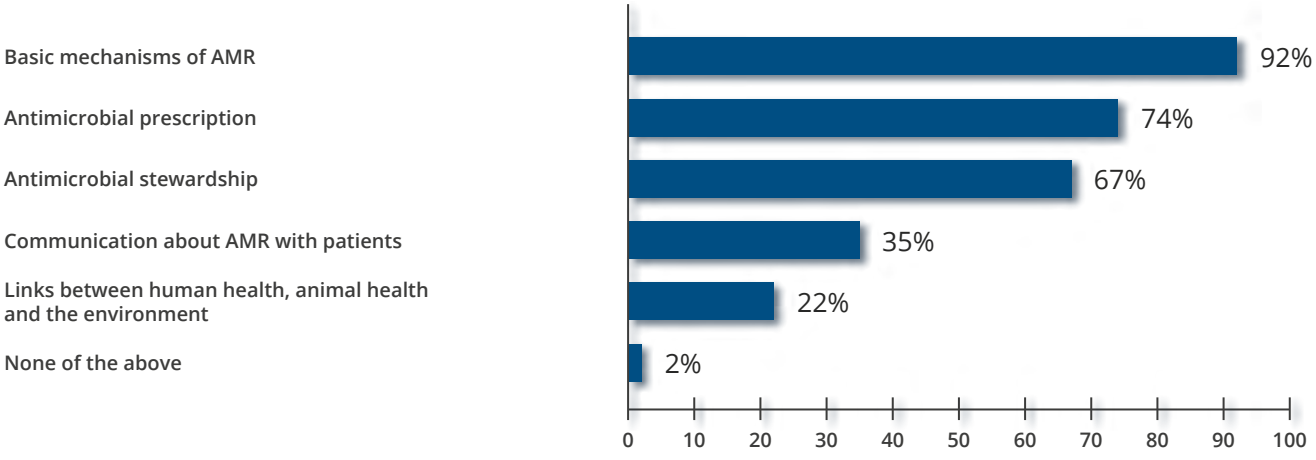
Over 80% of respondents were introduced to antimicrobial resistance in the second or third year of their curriculum. When asked their opinion about when the issue of AMR should be introduced, it was a nearly even split between the first three years with the small majority preferring the second year of study. Nearly half, however, recommended introducing antimicrobial prescribing in third-year study (see next section).

Of the students we surveyed, 68% did not have a course solely dedicated to AMR in their curriculum – 18% did receive a mandatory course and 14% were offered an optional course focussing on this topic. Overall, AMR was largely integrated into specific courses such as infectious diseases, microbiology, and pharmacology, but for some students the topic was also spread across different courses on clinical medicine.

The most prevalent aspects the courses addressed were the basic mechanisms of AMR, antimicrobial prescribing, and antimicrobial stewardship. Over 40% of respondents thought that these topics should be covered in greater depth – with some requesting further details on practical steps that medical doctors can take.

Three out of four students felt that particular aspects of AMR were missing from their curriculum – their responses show that they were particularly eager to learn more on the links between human health, animal health, and the environment as well as receive training on how to discuss AMR with patients.

Which of the following aspects does your curriculum address? (multiple answers were allowed)



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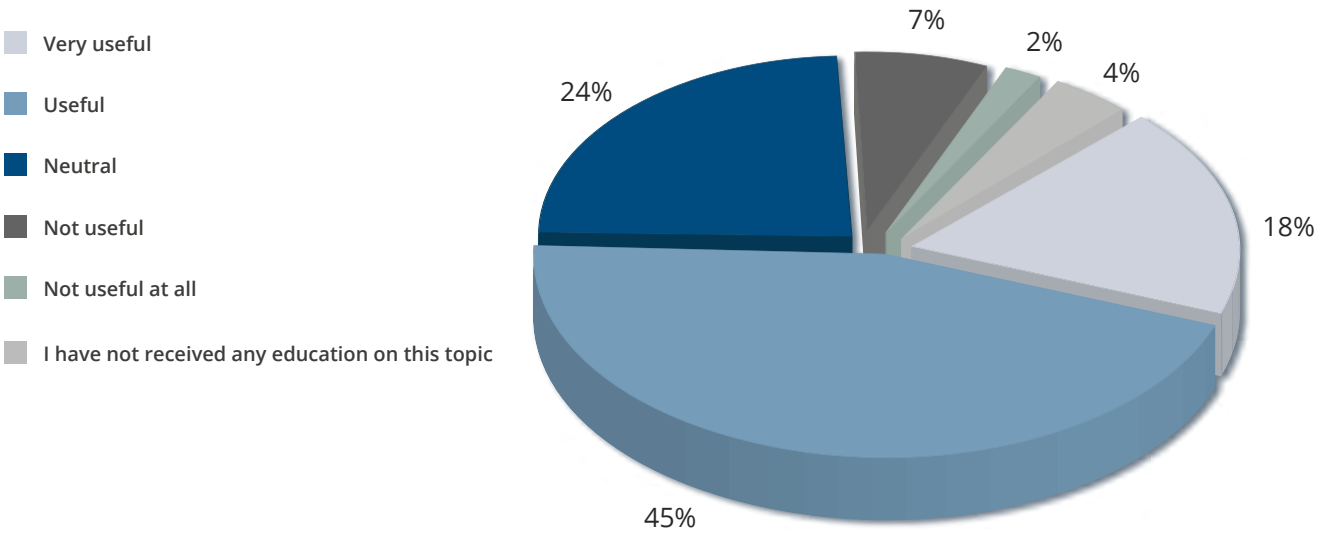
A surprising result was that over 80% of respondents had never heard about the 'One Health' approach during their studies; though it is worth noting that this figure significantly differs between countries of study: two thirds of students in Sweden knew about the concept for example, compared to fewer than 10% of students studying in the Czech Republic.

Nearly 80% of students had actually met patients with antimicrobial-resistant infections during their hospital rotations, but fewer than half of them were made aware of their hospital's antimicrobial stewardship team. A third of students surveyed did not know whether their hospital referred to specific antimicrobial guidelines whilst 70% of those who did said that they had referred to them at least once.

Antimicrobial prescribing in medical schools

Three quarters of students received lessons on antimicrobial prescribing with two thirds rating their education on antimicrobial prescribing as either very useful or useful. Nearly half thought that this should be a third-year subject.

How would you rate your education on appropriate prescribing of antimicrobials so far?



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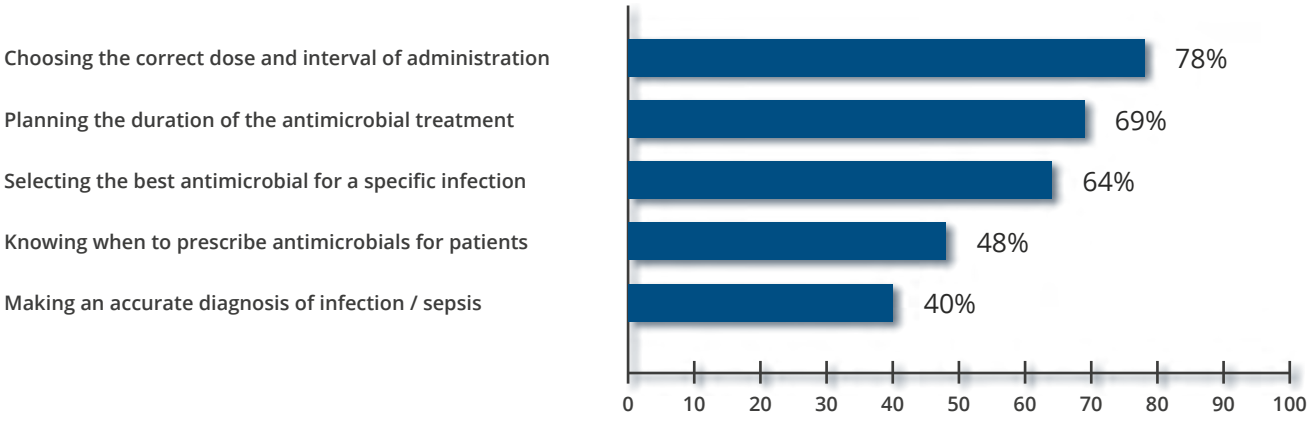
Students believed that their medical curriculum prepared them well or very well to accurately diagnose an infection or a sepsis, to understand basic mechanisms of AMR, and to appropriately prescribe antimicrobials to patients. A very large majority (90%) were eager to receive further training on antimicrobial prescribing during their studies, specifically: choosing the correct dose and interval of administration, planning the duration of the antimicrobial treatment, and selecting the best antimicrobial for a specific infection.

On which aspect(s) would you like further training? (multiple answers were allowed)



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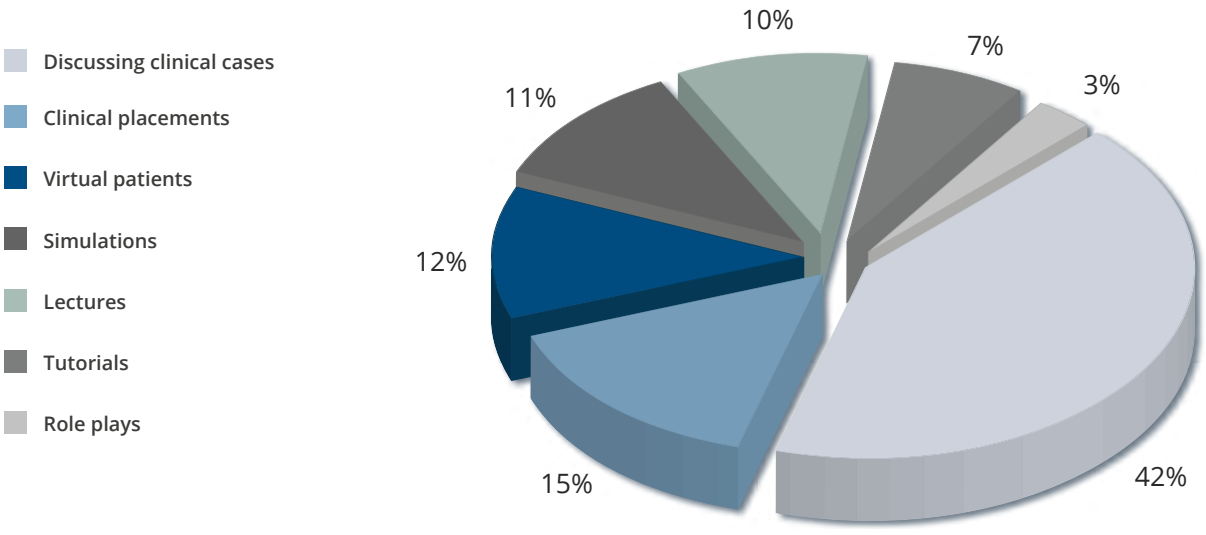
Discussing clinical cases was identified as the most appropriate format to educate medical students on antimicrobial prescribing, followed by clinical placements, virtual patients, and simulations; more traditional formats such as lectures and tutorials were less popular.

Which format do you think is the most appropriate to educate medical students on appropriate prescribing of antimicrobials?

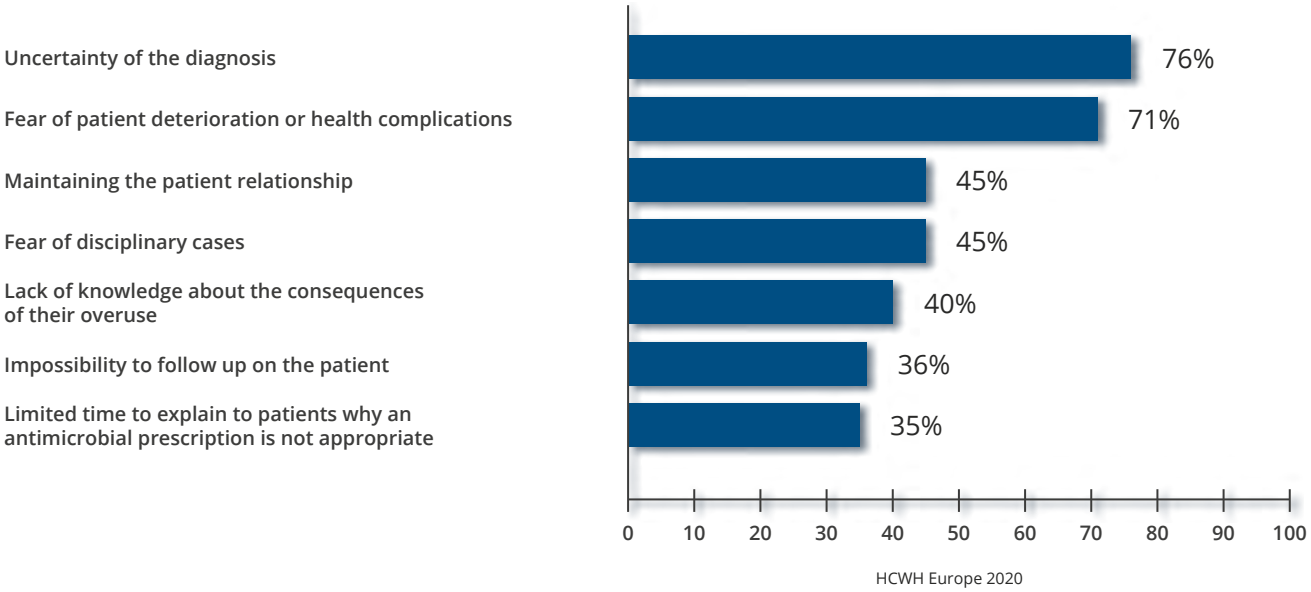


HCWH Europe 2020

It is worth noting, however, that medical curricula were not considered the most relevant source of information for medical doctors to learn about appropriate antimicrobial prescribing – continuous education and guidelines (international, national, and regional) were deemed more appropriate.

Students believed that uncertainty of diagnosis and fear of patient deterioration or health complications were the two most likely reasons why medical doctors might make unnecessary antimicrobial prescriptions – ahead of other concerns such as maintaining the patient relationship and fear of disciplinary cases.

Why do you think medical doctors might prescribe antimicrobials when they are not necessary?



Again, this is consistent with findings from the ECDC survey report on healthcare workers in the EU/EEA, which reported that the most common reason among responding healthcare professionals for prescribing an antibiotic when they would have preferred not to was the fear of patient deterioration or fear of complications.

According to the ECDC report, 43% of healthcare workers believe that these fears affected their prescribing decision at least once per week, and 11% at least once per day. Other leading motivations listed by the ECDC's respondents included uncertain diagnosis and impossibility to follow up on patients; limited time to explain the reason why an antibiotic prescription is not appropriate and maintaining the patient relationship were also mentioned to a lesser extent.[15]

SUCCESSFUL INITIATIVES TO ADDRESS AMR IN EUROPEAN MEDICAL SCHOOLS

Whilst our survey identified knowledge gaps and areas of improvement, a series of successful initiatives to enhance AMR education among medical students already exist in medical schools and universities across Europe. These might, however, not be well known because of silos in the academic sector or lack of information-sharing between universities.

This section highlights best practice from six institutions in the Czech Republic, Hungary, Ireland, Spain, Sweden, and the United Kingdom. These initiatives could be scaled up or adopted in other countries or regions – contact details of project coordinators are included and we encourage you to contact them for further information.

Antibiotic stewardship in interactive seminars

CHARLES UNIVERSITY, FACULTY OF MEDICINE IN HRADEC KRÁLOVÉ - THE CZECH REPUBLIC

Since 2018, the Charles University's Faculty of Medicine in Hradec Králové has offered an interactive course on antibiotic stewardship. This optional course is available to 15 students in their fourth or fifth year of study who have passed their microbiology exam; it is taught across five seminars each lasting three hours. The course aims to teach students the main principles of antibiotic stewardship and seeks to bridge an identified gap in the faculty's previous medical curriculum.

"Students, and even physicians, are not always aware that in some situations it is more appropriate not to prescribe antibiotics. There are also rules on how to choose antibiotics when they are needed. Microbiology reports could list five to ten antibiotics that the patient's bacterium is susceptible to, but some antibiotics need to be prioritised – they are not equal" – Associate Professor Helena Žemličková, MD, PhD.

The class starts by defining an antibiotic policy as a series of measures to ensure effective and safe use of antibiotics in human practice; the course also teaches students the ideal properties of an antibiotic: low toxicity, narrow spectrum, good pharmacokinetic and pharmacodynamic properties, and low potential for resistance selection. The first four seminars focus on nine questions that seek to guide students make the right antibiotic choice:

1. **What are the clinical symptoms?**
   Establish whether the bacterial infection is certain or likely and consider the urgency of the situation (e.g. focal infections, sepsis).

2. **Have appropriate clinical samples been taken prior to antibiotic treatment?**
   Select a treatment based on the confirmed cause of infection i.e. the infectious agent; treatment can be changed based on antibiogram and culture results.

3. **Which microbe is the most likely cause of the disease?**
   Consider factors such as patient's age, community vs. hospital-acquired infection, previous exposure to antibiotics, seasonal occurrence, and travel and work history.

4. **Which antibiotic is it best to use?**
   Indicate a choice and alternatives for infections with common bacteria such as *Escherichia coli, Haemophilus influenzae*, and *Staphylococcus aureus*.

5. **Is a monotherapy sufficient or is a combination therapy necessary?**
   Explore when combination therapy might be necessary e.g. for severe infections and infections likely to be mixed (e.g. abscesses, intra-abdominal sepsis) and list the bactericidal effect of specific antibiotic combinations.

6. **Which patient-related factors can influence the choice of antibiotics?**
   Consider patient-related factors such as chemotherapy and steroid therapy, liver and renal malfunctions, and pregnancy.

7. **Which method of administration should be chosen?**
   Oral antibiotic consumption is suitable for most common, uncomplicated infections but in some cases, such as severe infections, parental consumption e.g. inhalation, intrathecal, intravenous, might be more appropriate.

8. **What is the appropriate dose and dosage interval?**
   Consider factors such as creatinine clearance and weight in dosing and pharmacokinetic and pharmacodynamic parameters in dosage interval.

9. **What is the optimal length of the treatment?**
   Recommend lengths of therapy for bacterial infections such as *Haemophilus* meningitis, meningococcal meningitis, and pneumococcal meningitis.

The first set of seminars covering these nine questions concludes that inappropriate use of antibiotics in the community is common practice, but that improving prescription habits in primary care is possible. The course also highlights the need for a close cooperation between clinical microbiologists and general practitioners at the local level to achieve this.

The final seminar of the course is devoted to the role of clinical microbiologists in antibiotic stewardship programmes, giving medical students a better understanding of how things work in hospital practice. The seminar takes place in the university hospital's antibiotic centre, which is responsible for the release of antibiotics that require the approval of a clinical microbiologist.

Students learn about the role of the antibiotic centre in providing correct interpretation of culture finding and susceptibility results, proactively reporting major new results to the attending physician, and in presenting the system used for consultation with clinicians in guided antibiotic therapy.

This course also highlights the mandatory suitability review of antibiotic treatments after 72 hours based on the following questions: Does the infection respond to antibiotic treatment? If yes, is it the correct choice of antibiotic, dose, and route of administration? Is it possible to de-escalate the treatment or stop it? For how long should the treatment be continued?

It concludes that suboptimal use of antibiotics can be prevented by:

- Presenting suitable samples for culture
- Using microbiologically-confirmed diagnosis
- Appropriately interpreting microbiological examination results
- Reducing reliance on empirical broad-spectrum therapy
- Using valid local epidemiological data and following recommended procedures
- Improving multidisciplinary cooperation

For more information, please contact:

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Head of the National Reference Laboratory for Antibiotics, National Institute of Public Health

ECDC National Focal Point for Antimicrobial Resistance for the Czech Republic

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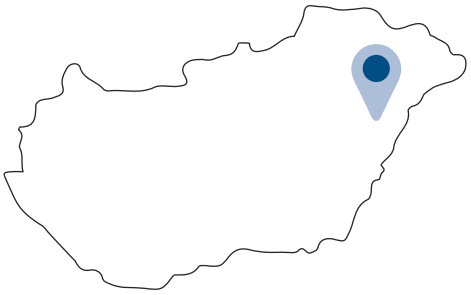
Using e-learning to teach prescription practices for infectious diseases

UNIVERSITY OF DEBRECEN, FACULTY OF MEDICINE – HUNGARY



The University of Debrecen has developed an innovative way to teach medical students how and when to prescribe drugs, including antibiotics. Since 2018, it has been running an interactive e-learning case-study course with a focus on infectious diseases, which allows students to make diagnoses and propose treatments in scenarios that simulate real-life conditions.

The optional course is available every semester to ten medical students in their fourth-year to sixth-year of study. The course is administered on an e-learning platform that offers a forum accessible at any time to both students and professors for Q&A, which gives them the freedom to manage their time as they see fit. The course covers a mix of microbiology cases, including in the fields of bacteriology, mycology, and virology.

Through the e-learning platform, students have to manage three fictional medical cases involving infections that can require different kinds of test (e.g. microbiological culture, x-rays, etc.). Based on fictional test results provided by their professors, they are then expected to make a diagnosis and if needed to propose a treatment for the given cases, which are then reviewed and students are given feedback.

Whilst the students might not yet be fully prepared to prescribe appropriately, the main objective of this course is to show the consequences of their prescribing decisions. *"Many doctors think that antibiotics are roughly equal, they do not feel that their prescriptions will have consequences. We try to emphasise this aspect in our e-learning course"* – Dr Gábor Kardos, Senior Lecturer who teaches on this platform.

Example of a clinical case on the e-learning platform

Ms Joan Halloway, a 76-year-old female visits your GP consultation in October; she has been your patient for 15 years. She lives alone, has three cats, and suffers from rheumatoid arthritis (which is treated with oral methylprednisolone), she is otherwise healthy and active for her age and is fond of hiking.

In today's appointment she if suffering from a bad cough which started five days ago after a walk in the woods, when she felt cold for the last hour of the walk. She expectorates yellowish sputum, is subfebrile (37.6°C) and feels 'tired and old'. Upon physical examination, inspection, and palpation do not yield any significant alterations. Upon auscultation, crackles and bronchial breath sounds are audible in the middle lobe of the right lung. Other positive signs are not found.

You have two written exchange opportunities to solve this case by 20th October. Please observe the deadline, as you have two more upcoming cases to solve.

Raising awareness on AMR in secondary schools with medical students

In 2018, the University of Debrecen also launched a programme to raise awareness on antibiotic resistance in secondary schools in partnership with its medical students' association. In this programme, medical students volunteer to go to secondary schools to teach pupils about the causes and consequences of antibiotic resistance, and to promote responsible patient behaviour.

In the first year, the pilot programme was run in three secondary schools – two in Debrecen and one in a nearby country town reaching approximately 170 pupils aged 15 to 18. The medical students were assessed beforehand on their understanding of the issue and received a short training on communication skills.

The course begins with a 20-minute presentation on the basic mechanisms of antibiotic resistance followed by a Q&A session with the pupils. The presentation introduces key principles e.g. What are bacteria? What is an antibiotic? Why don't antibiotics work on viruses? They illustrate the issue of AMR with real-life, practical examples and explain what can be done to improve the situation.

Before the course starts, pupils complete a 15-point questionnaire to assess their baseline knowledge of AMR – the impact of the course is then evaluated by using the same questionnaire two weeks after the course completed for comparison. In all classes, except one, the results showed an improvement with 78% of pupils scoring higher in the test and the average score increasing from 10 to 13 correct answers out of 15.

This programme is a good example of how medical students can engage with communities and have a positive impact on their education. Through community engagement they become more aware of antibiotic resistance and develop useful communication skills whilst promoting better understanding of antibiotics and good behaviour amongst young people.

Medical students who participate in the programme receive bonus credits that help them access further opportunities offered by the medical students' association such as international scholarships. The University of Debrecen would like to expand the programme in the coming years to involve more secondary schools and export the concept to other universities in Hungary.

For more information, please contact:

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Managing clinically important infections with antibiotics through case-based, technology-enhanced learning

ROYAL COLLEGE OF SURGEONS IN IRELAND, UNIVERSITY OF MEDICINE AND HEALTH SCIENCES – IRELAND

Medical students often struggle to interpret antibiotic guidelines and can have difficulty deciding which antibiotics to prescribe for bacterial infections because the choice depends on several variables. Providing a clinical context is crucial to improve their understanding of the case and their ability to make appropriate choices.

In 2013, the Royal College of Surgeons in Ireland (RCSI) introduced an online learning resource on antibiotic stewardship and clinically important infections to help medical students practice their antibiotic decision-making skills in a safe environment. It is made available to second and third-year undergraduate students as microbiology is a core subject at this stage of their curriculum.

Expanded in 2017, the online resource is designed to complement and support face-to-face teaching, e.g. lectures and case-based tutorials, as well as other online content. It contextualises the antibiotic management of clinically important infections in a virtual environment and strengthens the importance of antibiotics and their appropriate clinical uses.

"We adopt a mixed approach to learning – the online teaching allows students to learn at their own pace – they can access online materials over and over again and receive constant feedback on their understanding. It complements the message that we're giving in face-to-face teaching" – Dr Niall Stevens, Lecturer.

The online resource aims to improve medical students' knowledge on:

- The classification of antibiotics
- The mode of action of important classes of antibiotics
- The principles of antibiotic stewardship
- The mechanisms of antibiotic resistance
- The epidemiology of important resistant bacteria
- The adverse effects of antibiotics

It is divided into two main sections:

A theory-based component

The first module features six interactive tutorials that cover the principles of antibiotic resistance, antibiotic stewardship, mechanisms of resistance, and pharmacology. It is presented through a series of activities including animated videos and quizzes; students must achieve a certain level of understanding and standards to continue on to the second section of the course.

Students are introduced to the antibiotic guidelines from the Health Service Executive (HSE) of Ireland, the European Centre for Disease Prevention and Control (ECDC), and the World Health Organization (WHO); this serves as a resource hub for students who can easily access the guidelines and learn how to interpret them.

Clinical cases with virtual patients

The second module includes five clinical cases with Q&A-type activities on:

- Bacterial meningitis
- Cellulitis
- *Clostridioides difficile* infection (CDI)/antibiotic-associated diarrhoea
- Pyelonephritis
- Septic arthritis

Students are provided with the clinical information of a virtual patient – they are then required to make an initial diagnosis and choose an appropriate therapy. As the case progresses over time, more information becomes available, such as laboratory results and susceptibility testing results; students are asked to rationalise their proposed treatment.

At the end of the process, students review their patient management and self-assess whether they made the right prescribing decision based on how the patient's health evolved in the scenario. Students have to obtain a passing grade of 90% to access the next online activity and progress through the module.

Each clinical case is released immediately after the related topic has been covered in face-to-face teaching, allowing students to apply this knowledge and to complete their next case – this also promotes attendance in lectures. Students have unlimited attempts to complete each online activity, which allows them to learn at their own pace while receiving direct feedback.

On completion of the online module, students are expected to apply the principles of antibiotic stewardship and ensure antibiotics are used carefully, choose the appropriate empirical antibiotics to treat clinically important infections, interpret laboratory results, and rationalise empirical choice to an appropriate and more directed antibiotic.

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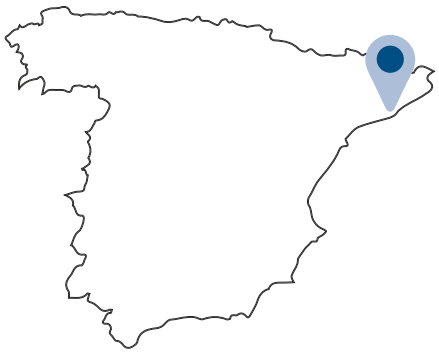
A multidisciplinary approach to antimicrobial resistance

UNIVERSITY OF BARCELONA, FACULTY OF MEDICINE AND HEALTH SCIENCES – SPAIN



Since 2017, Eurolife, a network of nine leading European universities in life sciences, organises summer and winter schools that bring together students, professors, and researchers working in life sciences. These short courses, open to MSc and PhD students from various fields, aim to promote educational and scientific interactions.

The first summer school in July 2017 was dedicated to AMR; it was hosted by the University of Barcelona's Faculty of Medicine and Health Sciences and organised in partnership with the Barcelona Global Health Institute (ISGlobal), a hub of excellence in research in global health that seeks to transfer scientific evidence into concrete actions.

Though their Antimicrobial Resistance Initiative, ISGlobal contributes to global research efforts on containing AMR and discovering novel therapies; they adopt a multidisciplinary approach ranging from research and training to analysis and technical assistance.

In total, 22 speakers and over 35 students from eight different universities across Europe participated in this pilot edition of the Eurolife summer school. The programme was divided into five topics across a 5-day course:

Day 1: The problem of multidrug-resistant (MDR) and extensively drug-resistant (XDR) bacteria

Students were given a general overview of the major issues related to MDR and XDR bacteria, such as global health implications, epidemiology, molecular basis, and economic burden. The afternoon was dedicated to a practical session on the basics of bioinformatics and networking opportunities.

Day 2: The tools

The second day focused on the tools available to identify antimicrobial drug resistance – students attended presentations on the mechanisms of resistance and rapid diagnostic tools. New methods were introduced with lectures about proteomics and next generation sequencing, and the implications these techniques could have for improved diagnostics in the future.

Day 3: Solutions and implementation

Participants were introduced to concrete solutions implemented at the clinical level and in different settings to tackle AMR, such as antimicrobial stewardship activities and measures to control hospital emergence and dissemination of MDR and XDR bacteria. They were finally given a practical case to define and control a nosocomial outbreak.

Day 4: The future

Students attended lectures on strategies for the design and development of new antibiotics from natural origins – they discussed alternatives such as antimicrobial peptides, faecal microbiota transplant (FMT), and phage therapies as an alternative to fight complicated infections.

Day 5: Academy-industry partnership to tackle MDR and XDR bacteria

The last day of the course looked at how to increase collaboration between academia and the private sector. Attendees discussed industry efforts to tackle MDR and XDR bacteria and the main aspects of patenting issues. Participants closed the day with a workshop on entrepreneurship and creative thinking.

The Eurolife summer school provided MSc and PhD students from across Europe with unique professional and personal development opportunities. The course offered an interactive and interdisciplinary programme on AMR in a highly stimulating learning environment that was of long-lasting value to the participants' future careers.

"The summer school was intense and very diverse, which is a fantastic way to approach the problem of AMR from many different aspects. Because of the large variation of research topics presented by the students, research questions were placed in a much broader perspective" – Ise Boekhoud, PhD student – Leiden University Medical Center (LUMC), who attended the course.

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Stimulating research on antibiotic resistance

UPPSALA ANTIBIOTIC CENTER, UPPSALA UNIVERSITY – SWEDEN

Sweden has been at the centre of AMR research for a long time; Uppsala in particular has long been considered as a hub of knowledge, expertise, and resources, hosting key institutions such as the Uppsala University, the Uppsala University Hospital, the Swedish Agricultural University, and the National Veterinary Institute.

In 2015, during the Uppsala Health Summit, Uppsala University announced the creation of the Uppsala Antibiotic Center – a multidisciplinary centre in antibiotics and antibiotic resistance research to respond to the complex issue of antibiotic resistance and the need for novel approaches in all scientific disciplines.

The Center brings together, stimulates, and supports research on antibiotics and resistance. It involves scientists and students from throughout Uppsala University to create a vibrant research environment and looks at antibiotic resistance as a global and multifaceted challenge that includes fields such as agriculture, biology, economy, healthcare, policy, sociology, and technology.

"We want to trigger a new generation of AMR professionals *with a unique, multidisciplinary and broad understanding of the problem and possible solutions to the resistance issue*" – Eva Garmendia, Project Coordinator.

The Center is fully funded by the university from 2016 to end of 2020 – an investment of SEK 40m (approximately €3.7m), and based on four main pillars:

1. Research

The Center is funding 14 PhD projects divided into four clusters:

- Basic understanding of the biology behind infection, treatment, and resistance
- Research & development to find new treatments and diagnostic tools
- Studies of appropriate use/access and proper stewardship of antibiotics
- Epidemiology, surveillance, and behavioural change

Two of these 14 PhD projects are linked to antibiotic prescription:

- *Antibiotic prescription in Swedish primary care consultations: A multidisciplinary conversation analytic study.* This project investigates the social and linguistic patterns of antibiotic prescription in Swedish primary care to explain the comparatively low rates of antibiotic use in Sweden and identify ways to further reduce antibiotic prescription within the Swedish healthcare sector. It will result in teaching resources for medical training and nursing programmes.
- *Understanding and improving antibiotic prescribing at a tertiary hospital.* This project explores the appropriateness of antibiotic prescribing at Uppsala University Hospital, incentives for prescribing, and measures to prevent inappropriate use. It will identify changes in behaviour to enhance the accuracy of prescriptions, reduce the risks of side effects for patients, and prevent the development and spread of multidrug-resistant bacteria.

The Center also supports three Associate Senior Lecturers working on projects within the areas of new antibiotics (medicinal chemistry), new diagnostics (nanotechnology), and new economic models (business studies).

2. Education

The Center offers a continuous and multidisciplinary education: public seminars, workshops (that offer students credit), and symposiums that bring together national and international company representatives, healthcare professionals, researchers, and students.

3. Innovation

Complex problems like resistance require new ideas and creative solutions. The Center fosters idea creation and innovation by providing networking opportunities and facilitating interactions with industry and the public sector and has developed contacts with companies and entrepreneurs working on the development of new antibiotics and diagnostic tools. The Center even has one "industry PhD student" whose project is jointly developed between the research lab and Gradientech – a life science company.

4. Awareness

The Center is involved in local and national outreach events such as science fairs to raise public awareness of antibiotic resistance, especially young people by using games, tools, and visuals. It also launched a podcast series, *The AMR Studio*, dedicated to the multidisciplinary research on AMR to raise the global and trans-sectorial nature of this issue.

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Tackling AMR challenges in a multidisciplinary Master's degree

UNIVERSITY OF SHEFFIELD, DEPARTMENT OF MOLECULAR BIOLOGY AND BIOTECHNOLOGY – UNITED KINGDOM

In 2019, the University of Sheffield launched a one-year Master of Science (MSc) course to train students for a career specifically dedicated to tackling AMR challenges. This course was conceived in collaboration with the Florey Institute, an institution that brings together researchers across the university interested in working on host-pathogen interactions and the field of AMR.

"Although some postgraduate and undergraduate degrees in other universities have an AMR component within their courses, there was no specific taught AMR Master's programme. What we really wanted to do was to make it an interdisciplinary course that covered a wide range of aspects relating to AMR – and not just focusing on microbiology" – Dr Claire Turner, Course Director of the MSc Antimicrobial Resistance.

The Master's programme, organised within the Department of Molecular Biology and Biotechnology, is mainly open to life science students, but the university also accepts medical students who wish to intercalate their studies – medical students in the UK have the opportunity to pursue a related research degree to delve deeper into a subject or a specialism.

Designed in collaboration with National Health Service (NHS) colleagues from the Sheffield Teaching Hospitals NHS Foundation Trust, the course aims to develop a global appreciation of AMR through public health and global political engagement. It provides students with real-world insight into multidisciplinary approaches through lectures with experts from the biotechnology and pharmaceutical industry, NHS Sheffield Teaching Hospital clinicians, and academic clinicians and scientists.

In the 2019-20 academic year, the programme consisted of six modules:

1. Infectious disease and antimicrobials

This module teaches students how infectious diseases and antimicrobial mechanisms work, with a specific focus on the history of infectious diseases and the infectious mechanisms in pathogenic organisms. Students have the opportunity to develop their skills in laboratory techniques through lectures and hands-on experience in labs.

2. AMR and current clinical practice

This module examines current clinical practice in relation to antimicrobial resistant infections in the UK and beyond; it describes the development of resistance and compares antimicrobial-resistant infections. Students also discuss the ethics of antimicrobial stewardship and treatment as well as the impact on clinical practice with lectures from medical school academics and NHS professionals.

3. Global policy, disease control, and new therapies

This module focuses on the most recent and cutting-edge developments in alternative antimicrobial strategies from across the university. It also provides an interdisciplinary approach to students and discusses the 'One Health' concept making the link with agricultural and environmental aspects of AMR through assignments, lectures, and workshops, which are provided by politics academics, social scientists, and colleagues from Public Health England and industry.

4. Developing communication skills

This module helps students acquire effective communication skills through tutorials and workshops. It allows them to develop editing skills through audio, film, and online publishing production, and presentation skills to ensure they can effectively engage with an audience. In this module, students also study the ethics of science communication.

5. Research and communication across the disciplines

This module aims to apply appropriate research and analytical methodologies to cutting-edge research from leading experts in AMR. Students attend cross-disciplinary research seminars and participate in a research symposium. They learn how to engage with primary research material and present and discuss findings with peers.

6. Research project in antimicrobial resistance

This module originally offered students the opportunity to conduct a three-month research project in an area of their choice in line with their future career aspirations, notably with the NHS and with the local Public Health England centre. Unfortunately, in 2020 it was not possible to provide wet lab-based projects due to the COVID-19 pandemic – instead in silico-based projects were performed, such as pathogen whole genome sequence data analysis and clinical infection data handling.

Overall, the programme offers an innovative approach to AMR education – a multidisciplinary overview of the existing challenges in the area together with an opportunity for students to develop transferable skills, from lab research to communication and problem-solving skills, through a wide diversity of teaching formats.

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CONCLUSION

Educating medical students on AMR is crucial to tackle inappropriate antimicrobial prescribing practices and optimise antimicrobial use in the healthcare sector. Yet three quarters of medical students we surveyed thought that specific aspects of AMR are missing from their curriculum and 90% of them called for further training on antimicrobial prescribing during their studies.

Drawing from the outcomes of our survey analysis and the best practice examples featured in this report, HCWH Europe proposes five recommendations for medical schools to update their curricula and ensure their students develop the necessary tools and skills to tackle this 21st century global health challenge.

1. Adopt a 'One Health' approach to AMR education

Over 80% of survey respondents had never heard about the 'One Health' approach to AMR during their studies. 'One Health' is a multisectoral concept that recognises that human health is tightly connected to the health of animals and to the environment. There is an urgent need to cut across sectoral boundaries and explain the role of the healthcare sector within a broader AMR perspective.

Only a third of students we surveyed had received education on the development of AMR in the environment – it is particularly crucial to close this gap and teach medical students about the impact antimicrobial residues have as a driver of AMR in the environment and the risk they pose to communities as they enter the environment from production through excretion to disposal.

2. Encourage critical thinking and practical training

It can be challenging to expand already-packed medical curricula. Instead of focusing on the theory, the main aspects of antimicrobial prescribing should be integrated into practical training. In our survey, discussions of clinical cases were identified as the best format to educate medical students on appropriate antimicrobial prescribing.

There is also a need to encourage critical thinking in place of rote learning. AMR education should focus on the principles of antimicrobial prescribing (e.g. de-escalation, sequential therapy) and on established guidelines so that medical students can learn to navigate difficult decisions when choosing treatments, correct doses, duration, and intervals of administration.

3. Embrace digital transformation

The world has changed – and so have students. AMR education should rely on new technology to complement face-to-face teaching, such as online forums, case-based e-learning, or virtual patients. Technology-enhanced teaching can offer a safe and entertaining environment to help medical students practice their prescribing skills.

Online learning also provides an opportunity for students to receive individualised and immediate feedback in a near real-life clinical context where they can base their decision on fictional test results. It can also allow them to learn at their own pace with the possibility of repetition as well as provide them with a better understanding of the consequences of their prescribing decisions.

4. Promote interdisciplinary teaching

AMR is a multifaceted issue at the cutting edge of diverse fields such as agriculture, economy, healthcare, and sociology. AMR education should promote a vibrant research environment that allows medical students to interact with peers from other disciplines (e.g. pharmacy, veterinary medicine) to better grasp the underlying challenges and develop a global appreciation of AMR.

Medical students should be offered the possibility to attend multi-disciplinary summer schools, intercalate their studies, and to participate in interprofessional education (IPE) programmes to promote cross-disciplinary research. This would allow students to receive insight into multidisciplinary approaches, develop new skills and tools to address the issue, and foster idea creation and innovation.

It is worth pointing out the role of educators in this area – to make this happen, university professors should be encouraged and trained across their career to adopt a different model of teaching that facilitates interdisciplinary interaction and education. Better mobility and exchanges among professors from different disciplines should therefore also be promoted.

5. Develop communications skills

Nearly 80% of our survey respondents thought that patients demanding antimicrobials unnecessarily was a very important or a moderately important driver of AMR in Europe and over 95% agreed that medical doctors had a role to play in informing patients about proper antimicrobial use. Yet only a third of students said that communication about AMR with patients was integrated in their curriculum.

Medical education should not only be about providing care, but also about building relationships – medical doctors are among the most trusted professionals in our society.[16] Medical curricula should therefore provide students with the necessary skills to educate, inform, and raise awareness on proper antimicrobial use as tackling AMR also depends on ensuring a strong adherence from the general public.

Whilst these recommendations aim to pave the way towards enhanced AMR education in Europe – some medical schools and universities already undertaking such initiatives too often go unnoticed. There is therefore a need to also promote collaborative networks and to share best practice between academic institutions to ensure creative ideas are disseminated and scaled up.

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Published: November 2020

Photos: Wavebreakmedia@istockphoto (cover), Sebastian@adobestock (p.6-7), shapecharge@istockphoto (p.14-15), WavebreakMediaMicro@adobestock (p.16), SolStock@istockphoto (p.20), SDI Productions@istockphoto (p.22), Jezper@adobestock (p.24), auremar@adobestock (p.26), gorodenkoff@istockphoto (p.28), joyfotoliakid@adobestock (p.30)

Health Care Without Harm (HCWH) Europe is the European arm of a global not-for-profit NGO whose mission is to transform healthcare worldwide so that it reduces its environmental footprint, becomes a community anchor for sustainability, and a leader in the global movement for environmental health and justice. HCWH's vision is that healthcare mobilises its ethical, economical, and political influence to create an ecologically sustainable, equitable, and healthy world.

Printed on 100% recycled paper using vegetable based ink.

HCWH Europe gratefully acknowledges the financial support of the European Commission (EC)'s LIFE+ programme, the Federal Ministry for the Environment, Nature Conservation, and Nuclear Safety (BMU) Germany, and the German Environment Agency (UBA). HCWH Europe is solely responsible for the content of this project and related materials. The views expressed do not reflect the official views of the EC, BMU, or UBA.