HOUSE OF COMMONS

Science and Technology Committee

Oral evidence: Antimicrobial resistance (AMR), HC 848

Wednesday 18 December 2013

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Written evidence from witnesses:

- Cambridge Infectious Diseases Initiative
- British Society for Antimicrobial Chemotherapy
- Society for Applied Microbiology
- Society of Biology

Watch the meeting

Members present: Andrew Miller (Chair); Stephen Metcalfe; Stephen Mosley; Pamela Nash; Sarah Newton; Graham Stringer; David Tredinnick

Questions 1-38

Witnesses: **Dr Pat Goodwin,** Scientific Consultant, Society of Biology, **Professor Laura Piddock**, Professor of Microbiology, British Society for Antimicrobial Chemotherapy, **Professor John Threlfall**, Member of Committee, Society for Applied Microbiology, and **Professor Sharon Peacock**, Professor of Clinical Microbiology, Cambridge Infectious Diseases Initiative, University of Cambridge, gave evidence.

Q1 Chair: I welcome our four witnesses this morning. Thank you very much for coming. It would be very helpful if, just for the record, you could formally introduce yourselves.

Dr Goodwin: I am Pat Goodwin. I am a microbiologist by training. I was a senior manager at the Wellcome Trust for over 20 years, where I was in charge of the infectious disease and public health programme. I am here today representing the Society of Biology, of which I am the honorary treasurer.

Professor Piddock: I am Laura Piddock, professor of microbiology at the University of Birmingham. I am also chair in public engagement funded by the British Society for Antimicrobial Chemotherapy, and in that role I am director of antibiotic action.

Professor Peacock: My name is Sharon Peacock. I am professor of clinical microbiology at the University of Cambridge. I also head the Cambridge infectious diseases initiative,

which is a multidisciplinary group of infectious diseases researchers, both basic and clinical.

Professor Threlfall: My name is John Threlfall. I am a consultant clinical scientist, a microbiologist by training. I worked for the Health Protection Agency officially until three years ago when I retired from it, but I came back straight away as project manager of some quite big European projects as a consultant. During my time with the HPA, I was director of the laboratory of enteric pathogens, which is the main reference laboratory for human salmonella, shigella and E.coli infections for England and Wales. At the present time, I am also on the European Food Safety Authority biological hazards committee. Today, I am representing the Society for Applied Microbiology as a committee member.

Q2 Chair: We want to start by looking at the Government's 2013 strategy. Do you think it will be successful in slowing down the spread of antimicrobial resistance in the UK?

Dr Goodwin: In principle, yes. It has highlighted the problem and the seven key areas. All the actions are reasonable. The problem is that we have known about this for many years. The first report highlighting the dangers of antimicrobial resistance—the Swann report—was back in 1969, and we have been sitting around doing nothing. The issue is how it is going to be driven forward. It needs leadership, political and professional will, international collaboration, because it is an international issue, a bit of imaginative thinking and quite a lot of funding as well.

Q3 Chair: You mentioned the seven key areas. Do you think all seven are necessary, or are there others you would add?

Dr Goodwin: I think they are pretty comprehensive, but they will probably need prioritising. Some of them may have an effect in the short term and some are longer term, and we need both prongs if ultimately we are going to deal with this situation.

Q4 Chair: Is there consensus?

Professor Piddock: We would add to it. BSAC obviously supports the strategy, but we are concerned that in the 2000 strategy there were at least 20 recommendations that have not been implemented. One of the reasons for that is almost certainly funding, but also IT infrastructure. We would recommend a review as to why some of those recommendations were not able to be implemented so that the recommendations that follow through into the 2013 strategy can be implemented. This will of course mean prioritisation. It will also mean working with others who are already active in this area; for instance, there are already others working on prevalence of resistance and prevalence of antimicrobial consumption. BSAC has a point prevalence study, and it now makes sense to combine efforts with Government Departments and learned societies.

Professor Peacock: I am optimistic that resistance can be driven down in some sectors. I agree entirely with my colleagues in relation to prioritisation. The report is very broad-ranging, and it would be good to get a better understanding of how one organises one's thoughts around what comes first. I am quite clear that there is not enough funding on the

table to achieve those aspirations at the moment. I did not see any new money in the report, and it is important to think about where that might be coming from. Leadership is going to be absolutely critical. The report mentions an interdepartmental high-level steering group, but what happens under that? It is all very well having that group, but who is actually under it to take action and corral the efforts?

The other issue I would reiterate is the global problem. The report is obviously UK-centric because that is what the strategy is around, but it is so important to realise that antimicrobial resistance is a global problem. Some of the issues that perhaps were not talked about in any great length in the report are over-the-counter prescribing in the developing world, which is incredibly important as a driver but very difficult to deal with, and also poor waste water management. If excreta with antimicrobial resistance genes goes into the waste, that will continually drive the environmental resistome. The other thing not mentioned is substandard and counterfeit medicines.

This is a very big picture. It would be good to get a much better understanding of how the UK goes forward and deals with its problem, but, at the same time, engages with the global community to understand the much bigger picture, because much of the resistance that we see in this country is potentially imported from other places. We have to recognise that and try to understand what is happening in the bigger picture. We cannot just say it is the UK alone and we do not have to worry about anybody else.

Q5 Chair: That is a very comprehensive answer. I want to pick you up on one point. At the beginning of your answer, you said you thought it would be effective in some sectors. Are there key sectors where you think it will not be effective?

Professor Peacock: There are some areas that are not mentioned much. One of the people who gave written evidence mentioned waste water, which is important. That would be a continual undercurrent, which could continue to flow back into hospitals. I did not see nursing homes mentioned at all. Nursing homes are a very important source—a reservoir of antimicrobial resistance. You have a vulnerable population who are repeatedly going into hospital and back to the nursing home, where infection control is not as tightly regulated, so there may be areas that are not touched by this report that need to be thought about. Where focus is concentrated, I think resistance can be driven down, but it is just a question of where you focus your efforts.

Q6 Chair: You talked about the high-level steering group. Do you think there ought to be named individuals with specific accountability identified? Are you talking about a structure that is transparent and it is obvious where the buck stops?

Professor Peacock: Partly, yes. It needs to be very transparent, but underneath that there need to be some themes—some thematic working. You need expertise on each theme, and working groups below that who are charged with the responsibility of considering the particular themes. There may be several themes that split out—not necessarily following the objectives—where learned people get together and try to work out what their priorities are. I do not quite understand how an interdepartmental high-level steering group is going to set the priorities of what they are going to do first.

Professor Threlfall: One welcomes the new publication of the Government's strategy, and the one-health approach is one of the key aspects. You ask whether this will work. I think it will work if it is acted on properly and with prioritisation. The strategy lacks certain areas which possibly should have been included in the overall document. Under my own issues, the strategy seems to lack an early warning response activity. All of us at this table have been involved when an antibiotic-resistant strain of bacteria has arisen very quickly and could cause major problems quickly. I do not think there is anything in that strategy—although there are certain areas about new technology being developed—that would be able to contain such an event happening. This is a real threat at the present time. In the past, MRSA has developed; we have had ESBLs coming through. If there had been a proper strategy in place when these were first observed, some action could have been taken, not to prevent the spread but maybe to minimise the spread of such organisms. This is a weakness of the strategy itself.

Secondly, there are various areas that, to my mind, have not been addressed in the strategy. For example, we have not talked about virus elements and areas like that, where you get antibiotic resistance coming through. Thirdly, there seems to be no mention in the strategy of antimicrobial substances other than antibiotics. In this respect, I am talking about the extensive use of biocides, which can in fact, if not used properly, promote antibiotic resistance, so there are areas of concern there.

I come to one of my particular interests over the years. The food aspects of this have been somewhat neglected in the strategy itself. It is mentioned in areas. There is collaboration among PHE, DEFRA and the Food Standards Agency in areas, but it seems to be somewhat neglected in the strategy. Maybe this could have been taken forward a little more strongly in the strategy itself. To go back to what I said initially, the big issue is that the strategy seems to lack an immediate emergency response capability.

Professor Piddock: I want to pick up the point raised about antimicrobial resistance. It typically comes into this country and is then disseminated and shared. In many other countries the use of antibiotics is a substitute for infection control and good public health. In this country we have a good public health system. We have taken on board good infection control in the hospital environment, but outside that people are not aware of what it means and how everybody, from nursing homes to the general public, could help minimise the impact of resistance by good infection control. Involving the public more and involving all health care professionals in good infection control practices and what they mean to their area would be well warranted.

Dr Goodwin: The veterinary side is also important. Much more needs to be done to tighten up what is happening there. As I understand it, infection control is virtually absent in animal husbandry.

Q7 Graham Stringer: There has been reduced prescribing of antibiotics in primary care, but resistance has continued to develop. Can you speculate on why that is happening? Should the policy of reduced prescribing of antibiotics continue?

Professor Piddock: Minimising antibiotic use in all areas, not just in human medicine but everywhere, is a really important part of resolving this problem, but it has to be recognised that bacteria can become resistant by acquiring bits of DNA from one another, and often

those bits of DNA will encode resistance to lots of different drugs or antibacterial compounds. Getting rid of the use of one type of compound or drug will not necessarily get rid of the resistant bacterium at all because there are other drivers. We also know that resistant bacteria are just as able to cause infections and hang around in the environment as antibiotic-susceptible strains, so there is no reason for them to disappear unless we make a real effort to eradicate them.

Professor Peacock: One of the areas we need to be more informed about is what is in the normal flora of healthy people. People who are healthy may carry antibiotic-resistance genes normally in their gut flora. We do not understand that very well. If you are looking at the effect of prescribing in general practice, you have to have a much broader understanding of what you are dealing with. If somebody comes into the clinic and needs a course of antibiotics, what is the likelihood that you will select that resistance in their gut? If it is there, the susceptible flora will be destroyed by the antibiotic but the resistant flora will remain. An important part of understanding what is happening in the community is really to understand what people are carrying at the moment and how much resistance there is in the normal population, which has not been a focus. In order to understand how to deal with community resistance, we need to understand that.

It is difficult to separate community from hospital. That is a model we have carried with us for many years, and I think it is flawed. Hospitals are focused on what they are doing, and in the community they are focused on what they are doing, but it needs to be considered as a continuum, because people move back and forth between the community and hospitals. It is difficult to say that GP prescribing will impact on community resistance, because it is much more of a melting pot than that.

Dr Goodwin: Another problem that contributes to this is lack of adherence. Patients do not always take their medicines as prescribed, and if they do not take their antibiotics properly they could be causing an environment which selects for resistant strains. This is particularly a problem now that we are getting so many more elderly, frail and other groups that are vulnerable to infection, who also may have difficulty in following the instructions for taking their drugs. Somehow we need to identify this group and see how we can help them take their medicines properly.

Q8 Graham Stringer: To summarise, even though we are being bombarded by resistant strains of bacteria from other parts of the globe, and resistance is continuing to develop in this country, you think the policy of reducing prescribing should remain.

Dr Goodwin: Yes.

Professor Piddock: Yes.

Professor Peacock: Yes.

Professor Threlfall: Yes.

Q9 Graham Stringer: That is a consensus view. The Surviving Sepsis campaign advocates prescribing broad spectrum antibiotics as an initial strategy to treat an unspecified disease. Is

that a scientifically sound thing to do? Is it a good way of preventing the development of antimicrobial resistance?

Professor Peacock: I think that is about saving lives. When somebody comes into hospital with serious sepsis you do not know the pathogen that is causing the disease. You also do not know the susceptibility pattern of that organism, so in order to save lives the strategy is to go in with your best drug, a broad spectrum antibiotic, which will cover a range of possibilities. That saves lives in its own right. We try to take cultures before we give antibiotics, if at all possible, so that we can grow the bacterium and see what the susceptibility pattern is.

Once we have determined that susceptibility pattern, we can come back from that very broad spectrum drug to a much more narrow spectrum drug that is unlikely to change the flora as much, but one of the problems is that it takes 24 to 48 hours from the point we have cultured the bacterium to work out what to treat the patient with—the optimum treatment. I do not think we can move away from broad spectrum treatment when we do not know what is wrong with the patient, because that would be associated with increased mortality from sepsis. What we could do is arrive at the answer much faster in relation to what bacterium is causing the infection and what the resistance pattern is. Therefore, we start to introduce the more narrow spectrum much earlier than we do at the moment. That is where I would put the focus on treatment: rather than changing the empirical prescribing, changing the targeted prescribing by getting a quicker answer.

Professor Piddock: The problem is that often it does not get changed from a broad spectrum drug to a narrow spectrum drug. The Start Smart Then Focus campaign has not been widely taken up throughout the UK. We strongly advocate that they look at the results and change. One of the problems we perceive at the society is that undergraduate and postgraduate education in microbiology, in particular antibiotic prescribing, is relatively weak, so physicians with a very ill patient will tend to err on the side of caution and maintain a broad spectrum drug when they could step down to a more narrow spectrum drug. We believe that, to use antibiotics appropriately and minimise their use so that the best drugs are used for the right patients to get the best outcome, we have to improve education.

Professor Threlfall: I am not a medical doctor in that respect. Professor Peacock touched on the area of rapid tests for deciding what the strains are resistant to. Some of the new technologies—the near patient testing—mean one can get a result, maybe within a couple of hours, on what the strains are resistant to. Broad spectrum antibiotics are absolutely fine, but one has to know what one is treating—the resistance patterns. Some of the new technologies, which will develop more rapidly over the next two or three years, will hone down this treatment quite considerably.

Q10 Stephen Metcalfe: I want to go back to something Dr Goodwin said about people taking the full prescribed course of antibiotics. Could you expand a little on that? You say it creates an environment where resistance can develop. I am not sure that I fully understand how.

Dr Goodwin: What you really want to do is knock out all the bacteria causing the infection. If you do not take the complete course, you may not knock out everything, and

because you have some low levels of drugs left in the body that is the ideal environment for resistant strains to arise. This brings us to a bigger point. We need to understand more about how antibiotics are metabolised and excreted in the body and how long they stay. Obviously, there are data from when drugs are first produced before they pass regulation, but we are all individual and we will metabolise and excrete these drugs in different ways. We really need to understand the individual variation a bit more so that we know a bit more about the parameters that will be required for a good course of treatment.

Q11 Stephen Metcalfe: I wonder how many of us have stopped taking antibiotics the minute we feel better and do not complete the course because we just do not think it is a good idea to take more drugs.

Dr Goodwin: That is the big danger.

Q12 Stephen Metcalfe: Where antibiotics are available over the counter in some countries, presumably there are no prescribing recommendations. It is a "Take them until you feel better" approach.

Professor Piddock: When dosing is recommended by the pharmaceutical company, it is usually arranged to have the maximum amount of drug in the body site that you are trying to treat the infection with, whether it is the lungs, urine or blood, to stay for eight hours, for instance, before you have another dose of the drug. We know the amount of drug that gets into a patient; you get a maximum level and it decreases over time. We hope that the troughs—the lowest levels between doses—still stay above the level we need to eradicate that bacterial pathogen. A lot of people think that three times a day means breakfast, lunch and dinner. It is not; it is every eight hours. If you stop taking them too soon, you may not have killed all the bacteria; they may still be there and they will just grow again. But the main issue with resistance is that bacteria grow much more quickly than we do. They double their numbers in 20 or 30 minutes, when it is something like E.coli. If in that original population of bacteria, which is a very mixed population, you have one or two bacteria in the millions and millions in that population, you make an environment for them to grow very quickly. We can do it in a lab over night. In a patient, the same can happen if they let the levels get too low.

We also know that bacteria acquire resistance in a very stepwise manner—little, little changes that add and add. If you keep having these troughs of levels, or you stop taking the drug too soon, those little, little changes add up to something where the bacterium can survive that environment.

Professor Peacock: May I pick up on over-the-counter prescribing? I worked in rural Asia for several years, so I am very familiar with over-the-counter prescribing. You can get one, two or 10 tablets—however many you can afford, or the pharmacist gives you—so it is completely unregulated, but one cannot be too simplistic about this and say, "It's a terrible practice and it just has to stop." If somebody has a very little amount of money in their pocket and cannot afford to see a doctor, they may be able to buy a handful of antibiotics, and that is potentially life-saving. The whole idea of saying that over-the-counter antibiotics are entirely bad is too simplistic. It is far more complicated than that. It is a bad practice, but one has to look at the effects of stopping it.

Professor Threlfall: I have been working with carbapenem resistance recently. If you go on the internet in this country, you can buy 15 different types of carbapenems, which are shipped to you from the far east. Quite often, these antibiotics are without proper formulation and regulatory controls. These can be bought in the UK through the internet, so it is not just a developing country problem.

Q13 David Tredinnick: Is there significant evidence that the presence of antibiotics in the natural environment affects antimicrobial resistance?

Professor Piddock: There are natural antibiotics in the environment. Many soil-producing micro-organisms, including some bacteria, produce antibacterial compounds as a way of competing with their neighbours for that ecological niche. Indeed, some of the compounds we now use in human and veterinary medicine have come from such micro-organisms. We are also now putting antibacterial compounds back into the environment, via water, for instance. When we take antibacterial products at home, what we excrete goes into the sewage system. There has been recent evidence to show that the way in which we treat our sewage here and in other high-income countries does not adequately or always get rid of all compounds. Some of them last for a very long time. More importantly, some of the antibiotic-resistant bacteria that we are also excreting last for a long time and are not completely eradicated.

What is the impact of that? The most immediate impact that has been put forward is that when those waters go on to fields where animals are being reared for food production, or there are crops that enter the food chain—for instance, there has been recent work on spinach—they can be contaminated either with the bacteria that have come through that route, which then enter the food chain again, or they can select antibiotic-resistant bacteria in that environment. Some of the resistances we are now dealing with in human medicine have come out of environmental bacteria which are then transferred into bacteria that are pathogenic to us.

Q14 David Tredinnick: In the Government's five-year AMR strategy, point 4—developing new drugs and treatments—talks about other options, "complementary tools for use in health, social care and veterinary systems." Have you given any thought to what these might be, if we are not able to fund new antibiotics? What would those further options be?

Professor Threlfall: There are various other therapies out there already that can be developed. I mentioned earlier the possible use of biocides and areas like that. There are bacteriophages that can kill bacteria. Some pretty hard research needs to be done to test these alternative therapies. There are the various probiotics and prebiotics as well, which may reduce antibiotics. There are areas out there, but quite a lot of further research is required to see how effective these potential therapies could be.

Professor Peacock: Fundamental microbiological research is important to keep in our scope, because that is how we will learn how bacteria do their job and how they are virulent. It is possible we can produce molecules that tackle the way they function—how they are virulent—and reduce their virulence, not necessarily kill them but make them less virulent. Used together with an antibiotic or another compound, that may be a way to tackle the infection without antibiotics. The prospect of not having any new antibiotics is

almost unthinkable in my mind, and I very much hope that is not the case. It is likely that new antibiotics can be discovered with further efforts.

Q15 David Tredinnick: Dr Goodwin and Professor Piddock both mentioned the importance of animals. The European Parliament has passed a resolution backing the phasing-out of antibiotic use for animals—the resolution on public health threat of antimicrobial resistance—saying it should be used as a last resort. You are nodding, so no doubt you agree with that. They have also found £1.8 million for a pilot research project to examine the effectiveness of phytotherapy, herbal medicine and homeopathic treatments for farm animals. Do you think this is the right thing to do?

Professor Piddock: We have to recognise that at the moment there are not many alternatives to using antibacterial drugs in animals, which can be very similar to those used in humans. They are different molecules but, as far as the bacterium is concerned, they work the same way; they are the same thing. That has been the issue.

Quite a lot of alternative strategies could be used in animals, and in other areas of non-human use of antibacterials, but we have to recognise that some of those also have to go through the same regulatory pathways as conventional drugs. My personal view is that now is the time to recognise that what we are recommending for use in animals we will never use in humans. Our track record is that, when we run out of things for humans, we say, "Can we have that animal product and repackage it and reuse it?" We have to get to the stage where what we want to use in humans we will not use in animals or other areas, and vice versa. My personal view is that things like bacteriophages for certain pathogens that come through the food chain, such as salmonella or campylobacter, would be a very good area actively to develop, because you would not want to use them in humans. The trouble with some of these alternative strategies, like bacteriophages, which are viruses that infect bacteria, is that bacteria can become resistant to those as well. With the knowledge we now have, we have to work out ways to minimise that resistance.

You mentioned phytotherapies and other types of herbal medicine that could be used in animals. The active components within all of these are antibacterial compounds, and some of those have been extracted and developed into drugs that we now use. We would have to decide if they are new types of chemicals that have never been used before. There is lots of natural product discovery going on at the moment—marine bacteria as well. Where are those going to be put? It comes back to priority setting, as Sharon mentioned earlier.

Professor Threlfall: You mentioned that antibiotics were being phased out for animal production. I think the actual requirement was to phase out the prophylactic use of antibiotics. Obviously, antibiotics are important for the treatment of animals when they are diseased; it is part and parcel of production. One is looking here at the prudent use of antibiotics so that they are only used as necessary. The British Poultry Council has now stopped using some cephalosporins on day-old chicks, but what is critical is the prophylactic use in animals, not disease-directed antibiotics.

David Tredinnick: Yes, you have corrected me. That is indeed what it says here.

Q16 Sarah Newton: I want to go back to what Professor Peacock was saying. I think you are quite right. We make an artificial distinction between community, primary care and acute care. A lot of people are going in and out, so we should have a whole-system approach. There are people who get infections that are acquired in the community and do not need to go to the hospital if they are well treated. They are quite minor types of infections, which, if swiftly diagnosed and treated, would stay there and do not need to go to the acute sector. Do you think it is more difficult to manage the acquisition of resistance within the community than in the hospital, because at least you have the four walls and the staff and the patient is in there? And if it is more difficult, why?

Professor Peacock: Rather than saying that it is more difficult, I would say that there are different challenges in the community versus the hospital. I do not think we have sufficient knowledge to weigh up one versus the other in terms of difficulty, but there are different challenges. Professor Piddock has already mentioned the fact that if you give an antibiotic in the community, you have to ensure the patient takes the medicine. What often happens is that you get a prescription and go home with it. You may not necessarily go back to the doctor, and they may not say, "Have you taken all your pills?" That is one issue in the community.

If you look at how difficult it is to control in hospitals, in hospital settings you have lots of very sick people all in the same place, many of whom are on antibiotics, having very complex procedures, with bits of equipment, operations and so on. There are completely different issues around trying to prevent the spread of pathogens that could infect somebody on a ward. That would come down to infection control, good intravenous line care, hand washing and so on.

I find it quite difficult in my mind to weigh one against the other and say that one is more difficult than the other, but from a hospital perspective, where I am generally based, it is difficult to peer over the fence to see what is happening in the community. If there could be a more joined-up view on infection control, prescribing practices and so on, particularly reaching to nursing homes—a relatively untouched area in terms of research on how organisms are being transmitted and how effective infection control is—that holistic approach would be important.

Q17 Sarah Newton: To what extent is that related to something that was said earlier about IT and data sharing? A patient could be prescribed by an out-of-hours GP who did not have all their records; they might have a different set of antibiotics. If a patient had an unplanned admission to a hospital, the hospital would not have their records if they had to treat them. This was touched on by others. To what extent is there an issue about lack of IT or joined-up information about the patient and their history with antibiotics?

Professor Peacock: I will give a brief answer, and then Professor Piddock may want to come in. IT systems absolutely underpin good prescribing. They can assist in good prescribing in that they can remind people what is the best drug to prescribe, and then people can be tracked to see whether they have been prescribed that. Audit—looking at what we are doing in terms of our prescribing practice—absolutely necessitates good record-keeping.

In addition, if we want a broader view of whether somebody has got better or has developed resistance, looking at the emergence of resistance over time with antibiotic use will also take very careful record-keeping. At the moment, we can look at the tonnage of drugs prescribed by a hospital, but, when it comes down to individual people, it would be better to have antibiotic usage by person head and their outcome information. All of that absolutely requires IT and good record-keeping. Looking forward, IT is really critical.

Professor Piddock: This was obviously a feature of the 2000 strategy as well, trying to link up all the information that is available. We are all aware of how difficult it is to link up all these different sets of information, because they are often kept in different places. One suggestion is that individuals with smartphone technology can start carrying their own information with them, but that will not allow you to do nationwide prevalence of use or resistance. It is a significant challenge, and if we are to tackle this properly and understand the issues, in particular for the UK population, we have to get a grasp of it. We have to know what is being used and where.

A study of GPs published by a group from Cardiff university showed that GP prescribing varied widely in the UK but was not clearly associated with any difference in outcomes for specific infections. We need to understand the drivers for people to prescribe in certain ways, and whether they impact on the resistance problems that we are seeing in this country.

I come back to something Sharon said. We have to understand what is out there. If we cannot see what is over the wall, we are not going to be able to manage it, because it will hit us at the time we least expect it. We need to understand what the general public are carrying around with them in their gut, particularly those individuals who are going to be more vulnerable to infections. We would then understand whether there is any association with use in that particular area or GP practice. We would also be forewarned, if they came into hospital, as people often do, particularly through the nursing home route, about what you would perhaps not use if you have a patient presenting with sepsis.

Q18 Sarah Newton: How could that be done?

Professor Piddock: I am not an IT specialist, but my instinct is that this is a huge and significant challenge to our health care sector. I could not possibly advise you.

Q19 Sarah Newton: We have heard some quite alarming information about how quickly we need to move; but we are talking about the next 10 to 20 years waiting for all the different parts of the system to connect up, and hopefully some IT can do that. That seems to be quite a long solution. What about other ideas, like gathering data from mass screening of the population?

Professor Piddock: You are quite right. Mass screening would be good. I said earlier that there are other groups and societies already active in this area; for instance, there are point prevalence surveys. By default, that means it is only one single point in time, or several points in time, rather than continuous, but it gives us a good snapshot of what is happening. We are doing that for antimicrobial use, and there are resistance point prevalence studies collected on a European-wide basis. The problem with those is that we

are targeting particular areas, say, hospitals, particular patient types and often particular pathogens, so we are only looking for what we are warned might be there. If we are going to start to do surveillance properly, and understand the epidemiology, I propose we start looking for resistance to particular drugs rather than particular pathogens.

Professor Threlfall: IT is vitally important, but there are other areas of IT that we have not touched on today. At the moment, some very interesting new technologies are being used. I have not mentioned whole genome sequencing, which is producing a vast amount of information about organisms, flora or whatever is going on there. To analyse some of the information that is produced by these new technologies, one needs tremendous bioinformatic skills. Bioinformaticians who can do this are few and far between. It is also linked to IT. To make the best of these new technologies, it is very important that bioinformatician training is given a high priority, so that this new information can be assessed. That will give information about antibiotic levels in the community, bacteria in the community, and so on. This is one of the areas that needs very rapid development and funding.

Q20 Sarah Newton: That has certainly been the subject of previous inquiries. My last question is one that has been touched on in previous conversations: the risks related to resistance coming into the UK from abroad. Perhaps each of the panellists could give a best estimate of the scale of the risks, and comment on the resistance that is coming into the country. Perhaps Dr Goodwin would like to start.

Dr Goodwin: It is very difficult to predict the scale of the risk, because you never quite know what microbes are going to do. Microbes do not respect national borders, so a resistant bacterium arising in Asia can be in the UK in no time at all. We really need surveillance on a more international level. This is not easy; it requires international collaboration and a lot of money. There is a model in the malaria world. There is the worldwide anti-malarial resistance network, which provides tools and training for scientists and clinicians in developing countries where malaria is present. It has been very useful in identifying resistance genes that have emerged in Asia. It requires a lot of money, and it would not have been possible without a lot of input from the Gates Foundation. That would be the ideal.

Q21 Chair: You are moving from an area that has developed in a specific tropical disease, which has a cohort of workers focused on it, to say that the same principle needs to be extended to the whole of the medical training programme. That is a very large step.

Dr Goodwin: I am talking about antimicrobial resistance.

Q22 Chair: But if you are saying that there is a model that could be developed to cover antimicrobial resistance, it would require a major training element to be instilled in every course for the training of the next generation of doctors.

Dr Goodwin: Indeed.

Professor Peacock: I agree that it is very difficult to be exactly sure how much resistance is coming from overseas. Coming back to the point about mass screening, I do not think you can do mass screening all the time. It is just not going to work for bacteria or pathogens, because our gut flora changes. If we eat something with bacteria in it, that may be incorporated, so it is a bit of a moving feast.

There are a couple of things. You could do targeted global surveillance; it does not have to be across the piece. You identify your key targets and do global surveillance—sentinel surveillance like weather forecasting—to look for alerts. That would have to be across the world at the sentinel sites, but it would be easy to come up with three or four really important targets that you would want to see arising. I think surveillance could work, and it would not have to cost the earth—it would obviously cost.

There are things we can do. For example, people return from overseas having received treatment. We know that medical tourism happens. There could be better practice around how we deal with those patients. If a patient comes from a certain country, our practice at Addenbrooke's would be to assume that they carry multidrug resistance until proven otherwise. We do not put them on the open ward; we put them in a side ward, and we screen them. We look for MDR, and, if they have multidrug resistance, they are barrier-nursed. They stay in the side room, and they are less of a risk to the rest of the population.

We all travel all the time, so how can you regulate that? There are some really important hot areas that you can tackle—for example, people coming from overseas, who could be very vulnerable to carrying multidrug resistant pathogens. You then want to contain it and not let it spill out into your hospital. There are issues you can deal with relatively cheaply in that regard. That is just tightening up on best practice on returning patients.

Professor Piddock: The challenge, though, is to understand the scale of resistance in patients in the community who end up going into hospital. Your question was how much is coming in, and can we predict it? I do not think we can predict it, other than to say that it will increase unless we do something. I quote the example of Italy and resistant bacteria to the carbapenem drugs, which we increasingly use quite widely in the UK, because of worries about resistance to other types of antibiotics. There is up to 40% resistance in certain patient groups—seriously ill patients and those with bloodstream infections—who are now resistant to carbapenems and cannot use those drugs any more. That is Italy. A year ago, we would probably have mentioned Greece. In their ICUs, they now have significant challenges in finding antibiotics that will be effective in those patients.

We cannot give you the scale of the problem, other than that it is going to increase from where we are now. We need to understand the vulnerable groups in the community who could come into hospital with challenging scenarios—for instance, they might have sepsis—where you want to get the right drug as quickly as possible. It comes back a step again. Who are you going to screen to find out what is out and about so that you are forewarned as to how to treat them best?

Professor Threlfall: Can I bring in the point about infections being introduced to the country through imported foods? They are frequently contaminated with gut bacteria that cause infections, and these can be quite serious at times. A good example is the severe outbreak of a certain strain of E.coli in Germany a couple of years ago, resistant to third and fourth generation cephalosporins. These were not necessary for treatment of those

strains, but once more it shows that those strains had picked up highly formed resistance. Imported foods have been neglected somewhat. Laura mentioned it earlier. Screening these for bacteria can be an extremely important point, and they can be reduced by proper preventive measures being taken. For example, within the EU at the moment, salmonella in poultry has been reduced by various legislative measures. As a result, the level of salmonella bacteria with resistance to quinolones and fluoroquinolones has dropped significantly in that respect. Areas like this have been somewhat neglected and may need to be properly looked at with a definitive programme.

Q23 Stephen Metcalfe: I want to go back to multidrug resistance. What are the main concerns about MDR?

Professor Piddock: The particular concern is gram-negative bacteria because they are inherently multidrug resistant before they acquire any of the other resistances. It has always been technically challenging to find effective drugs, which is why the majority of antibiotics developed and used today are good against gram-positive bacteria—for instance, staph aureus.

The challenge now is that the few drugs we have against gram-negative bacteria are becoming much less effective, such as carbapenems and fluoroquinolones, because they then acquire these resistances. It is very challenging to find an effective drug, so people are having to go back and use older drugs like colistin, which have adverse reactions in some patients. The challenges are to discover or develop new treatments. It has always been technically challenging, and it is even more so now. Multidrug resistance is the big issue. The current issues are carbapenemases and ESBLs, on which I am sure you are well versed because you have had lots of written evidence, but we do not know what tomorrow's challenge is—whether it is going to be colistin resistance, because that is the pressure. In certain bacteria, it is increasing as we speak.

Professor Peacock: Multidrug resistance is a catch-all phrase in many ways, but it means many different things. One of the key things about multidrug resistance is that it can be cumulative in the same bacterium. They will acquire one resistance gene to one particular drug and then they will acquire another resistance gene to another type of drug, so the level of resistance in that organism starts to stack up. They can become extremely drug resistant. That is another issue. Over time, we are seeing an increased proportion of bacteria that have these extremely drug-resistant phenotypes. It is not simply that MDR is here; there is still room for escalation.

Q24 Stephen Metcalfe: Are there any pathogens in the UK that are now completely resistant to antimicrobials?

Professor Peacock: Isolates that are utterly resistant to everything are very rare indeed. We tend to see people who come in with infections where the organism is resistant to the thing you would ideally like to give, and perhaps even the second-line or third-line thing you would ideally like to give. You are looking at a patient who can only be given old drugs—drugs that are toxic that would not have been used a few years ago. Laura mentioned colistin, which is a good example. It was considered to be very toxic to the kidneys, so was never considered for use, but we are now reverting in desperation to those

older drugs, and in combinations. We will often put drugs in combination that we would not normally use. We are at a stage where often we are giving sub-optimal therapy rather than absolutely no therapy and the patient would therefore die.

Professor Piddock: That is a real challenge. You end up giving drugs that you know will give a poorer outcome. For some patients, while the bacteria may be susceptible to some of the older drugs in the lab, you simply cannot give them because of their other underlying conditions. Are there any truly multidrug resistant bacteria in the UK? Probably not, because we can always find something. But are there patients for whom their infections are unlikely to be treatable in the time frame we need to do it? Yes.

Q25 Chair: How accurate is our information about which pathogens are currently resistant to which drugs?

Professor Piddock: As in which species can be resistant to carbapenems, for instance? I think our information is fairly accurate.

Q26 Graham Stringer: Our briefing notes say that certain TBs and gonorrhoea are now resistant to all antimicrobials. Is that the case? You seem to be casting doubt on that.

Professor Piddock: I do not think we are casting doubt, but in terms of the UK population such bacteria are very rare. As to gonorrhoea, we have not got to that stage in the UK yet. I am saying "yet". Again, that is an infection that is transported around the world, so there is no reason why it would not come here. That is a good example of a community infection that is basically untreatable, but the patient is unlikely to die immediately. They will carry that infection and go on to have all sorts of other conditions arising from chronic gonorrhoea.

Professor Peacock: We should not get too caught up with fear. There are a very small number of people with completely untreatable infections. We have to look at trends over time. At the moment, we are seeing increasing numbers of patients with multidrug resistant bacteria. We will reach a stage where untreatable pathogens will emerge. We do not see that very often, but, given the trends, it is very likely to happen.

The point Laura made is really important. You may have a pathogen that can be treated with an old drug, but it is not a good drug; it is not the optimal drug, so you are still treating somebody who will have a poorer outcome than they would if they had the ideal drug for that particular condition. We should not feel in any way reassured that we do not see completely resistant organisms very often, because we are not doing so well when we cannot use the best drug.

Professor Threlfall: Some infections do not require antibiotic treatment. For the most part, the fact that they may be multi-resistant is irrelevant to the treatment regimen required. I am talking about some of the gut bacteria, for example. Even though the organisms are multi-resistant, for 90% or 99% of the population those bacteria do not become invasive and treatment is not necessary. It is when they become invasive that they cause a problem.

Q27 Stephen Metcalfe: You were talking about using older drugs that perhaps are not ideal. Presumably, as you start to increase the use of those, resistance to them will also increase.

Professor Piddock: Absolutely. Bacteria evolve to survive in whatever environment you put them in, whether it is hot, cold or the presence of antibiotics. We have to use the scientific knowledge we have to minimise the selection of such resistant bacteria, and to minimise their transfer between people so that the infection is controlled. We have to understand how bacteria share resistance genes and how they develop in that stepwise manner. We are now in a much better position than we were even 10 years ago to understand the scientific basis, but we are still not there. If we want to do something very quickly, we need to understand resistance much better. We can do that quickly while we are waiting for new drugs to be developed, or other strategies, over the next 10 or 20 years. We could really get to grips with understanding resistance, knowing what is there, how it works and how the bacterium responds to that pressure, and we can use what we still have much better.

Q28 Stephen Metcalfe: That sounds like a very sensible approach. Is there any evidence that the process is cyclical, by which I mean that, as a resistance is developed, it loses resistance to a drug that it might have had resistance to at some point in the past?

Professor Piddock: There have been publications in some very worthy journals that have suggested this, but in the clinical or veterinary environment, once bacteria become resistant, there is no reason for them not to be. They have often developed other compensatory mutations to allow them to live with the impact of that resistance mechanism or resistance gene. Unless it is deleterious to that bacterium, it will keep the resistance.

Professor Threlfall: There have been examples whereby plasmids have been lost from strains and the strains then become less resistant. An important factor over the last few years is that some of these plasmid genes have themselves become what are called resistance islands. They have become incorporated into the bacterial chromosome. Once in the chromosome per se, they are stable for generation after generation and generation, so they are not lost from those organisms.

Q29 Stephen Mosley: Professor Piddock, in your penultimate answer you talked about understanding microbial resistance. I want to move on to the monitoring and surveillance of resistance. Do you think there is a need for more information about the incidence of antimicrobial resistance?

Professor Piddock: At the moment, our national reference system is by referral from microbiology labs in hospitals. We do not have a system where all labs that grow bacteria monitor and share that information nationally. That is one of the areas where we think IT would improve the sharing of that information. We have to decide whether we are going to continue with the way we have historically monitored resistance, such as how we monitored MRSA—now we are monitoring E.coli that grow in the bloodstream and infections, for instance—or we say, "We don't care what the bacterium is—what the pathogen is; what we care about is the resistance to this key drug, because that is so

important to us." If we are going to do monitoring, we have to decide how we are going to prioritise our monitoring and focus our efforts.

Professor Peacock: I agree; it's deciding. I mentioned joined-up surveillance previously; it's getting your key targets for the antibiotics that you really want to detect. We do not do surveillance that well as a country; as Laura mentioned, it is rather voluntary and things are not referred to a reference laboratory on a consistent basis. We would benefit in this country from a joined-up system of surveillance, and the reporting of surveillance, for resistance to key drugs that are used in humans.

Dr Goodwin: It would be very useful if we could integrate research and surveillance much more—in other words, use the data that we are getting from surveillance to ask research questions, and when we get the results from those research questions, feed them back to inform our surveillance and improve on it.

Professor Threlfall: There are some very active surveillance requirements under European legislation, particularly for bacteria in food animals. They have to be screened at regular intervals for salmonella, campylobacter and resistance to a harmonised panel of antibiotics throughout the EC member states. These are published on a yearly basis in various reports, so one can see what is happening.

The big problem with some of these surveillance requirement networks at a European level, and we contribute to that, is that they tend to look at pathogens and not at the commensal organisms which quite often harbour the resistance genes and transfer into the pathogens themselves. There are some good surveillance networks in Europe. For example, EARS-Net is a very good surveillance network which gives an overall impression of what is happening throughout Europe. Personally, I think the UK is lacking on the surveillance aspect, and it ought to collaborate much more with the European agencies who are dedicated to this surveillance work.

Q30 Stephen Mosley: Two points come to mind. Where are the gaps, and how should we go about it? Should it be driven by a bottom-up or top-down approach?

Professor Threlfall: There are several gaps already. I mentioned the rather unco-ordinated surveillance happening in the UK for some of the human pathogens. That is absolutely correct. When new antibiotics arose—we talked about the carbapenems a few minutes ago—there were no screening systems in place until very recently, to look at, say, the occurrence of such resistance in bacteria from food animals, although new legislation has been recommended whereby this will actually now take place. There are gaps in that area. This should be looked at. There should also be surveillance of some of the commensal organisms, which are the source of such resistance, as well as the pathogens.

Professor Piddock: By understanding what resistance is out there we can understand how the bacteria have changed. That will inform not just clinical practice and what drugs to use but also discovery. By understanding how bacteria change themselves, we can search for new ways that are active against that mechanism of resistance, for instance. There is a lot of work going on with gram-negative bacteria to understand why we cannot get drugs into them very easily, and why, when we do get the drugs in, they are promptly pumped out. You can change the molecules at a chemical level to get in better, if you can understand

what is keeping them out, and, likewise, what is making them go out again. Can we target those systems with new molecules or other strategies? Can we turn these systems on or off? The research is fundamental in knowing what is there and how it has become resistant, to inform both clinical practice and new ways of treating.

Q31 Stephen Mosley: You are talking about the good things that are being done in terms of animal welfare and resistance in animals. With humans it is slightly different. You go to the doctor and you are given a packet of medicine. If you feel better you do not go back, do you? Is it a lot more difficult to monitor resistance in humans, because essentially there is no way of getting people to go back and checking them regularly, in the same way that you do with animals? Is there anything we can do about that?

Professor Threlfall: When I was the director of a reference laboratory, we screened all the organisms that came into the laboratory—enteric pathogens—for resistance to palliative antibiotics. They were clinical referrals in most cases, so we had a very good handle on resistance to those organisms within the UK—in England and Wales, and in Scotland. That was a properly done exercise. It gave us a good handle, but it was not particularly surveillance; it was looking really at clinical isolates. There was no real surveillance.

Q32 Stephen Mosley: Again, those were only people who had been in with complications and had not got better.

Professor Threlfall: Mainly. There were a few people who were asymptomatic, and different outbreaks, but it was mainly those areas.

Professor Piddock: It is probably better in humans than in veterinary medicine.

Professor Threlfall: It gave us a handle, but there were no surveillance schemes per se in place for the gut organisms. There are for the more serious infections, but not those organisms.

Professor Piddock: DEFRA had a globally recognised flagship programme on antimicrobial resistance, which was cut and cut and cut. Now we are at the stage where the surveillance of resistance in bacteria in animals is at an absolute minimum. There is no gate-keeping there. When I was on ACMSF, we talked a lot about antibiotic resistance in food-borne pathogens. It is not just about rearing animals in this country for food production. Much of our food is imported. It is not just what we do here that affects our population; it is what they are eating that comes from outside. Then we get into trade issues. This has been looked at in great detail over the years by ACMSF. To come back to monitoring in animals, I do not think we are doing it as thoroughly as we used to.

Q33 Pamela Nash: Each of you has discussed briefly this morning current and possible solutions to this problem, but it would be helpful if you could outline for us all the current research areas that aim to solve the issue of antimicrobial resistance. Would it be possible to describe the different areas of research going on in the UK at the moment?

Professor Peacock: That is a big one.

Professor Piddock: I will start from basic science. We are very good in the UK in many areas of basic bacteriology, and what could then be a platform for antimicrobial research. We have considerable expertise in natural products, microbiology and chemistry. We have good expertise in understanding the newer mechanisms of resistance, such as carbapenemases. We have centres of excellence in understanding how certain bacteria infect the host. We have pockets of excellence in all of these areas, which are recognised throughout the world. We have a very good network of numerous labs working on mechanisms of resistance.

The main problem is that this area is vastly underfunded. The all-party parliamentary group on antibiotics has just produced a report, which we can make available to the Committee, on the level of funding to UK researchers in this area. It is 0.67% of the total funding that has been available since 2008. That means that we are not able to exploit and capitalise on our own research in a timely manner. It goes all the way through from discovery to clinical research. I just mentioned basic research, but I am talking about funding for all areas. We need to do so much more, and we could be doing so much more. We have the strengths, but we are just not able to exploit them.

Professor Peacock: I would find it quite difficult to overview all of our research strengths in just a few minutes. I would like to pick up something where I think England is a world leader: genomics used for surveillance and outbreak investigations. There are several groups in England who are developing considerable expertise in using whole genome sequencing technologies and applying them to microbes to understand how they transmit from one person to another and using them for outbreak investigations. We have a very credible research base in England in relation to that, so I think that is something that we are doing well. It could also be applied to surveillance. If we want to look at the spread of antibiotic resistance in a country or, more broadly, in Europe or the world, you could use genomics to look at the transfer of antibiotics moving around the globe.

Q34 Chair: For clarity, on the point you have just made, I do not think you meant to say just England. I think you would agree there are some pretty good genomics going on in Edinburgh, for example, and other places.

Professor Peacock: Of course. I shall delete that and say "UK".

Chair: I just want to have it clear on the record.

Professor Peacock: Absolutely. In terms of what we could apply to antimicrobial resistance, that is something we should bear in mind because we are good at that.

Dr Goodwin: I agree entirely with Sharon. A lot of this work was funded by the translational infection research initiative, which was a joint funding effort by the Wellcome Trust, when I was the lead there, the MRC, the Department of Health and the devolved Administrations. It was really looking at translational research in this area. It funded some of the genome sequencing work that Sharon has been talking about. It also funded a centre at Imperial College where they are looking at prescribing practices, predicting patients who are at risk and looking at things like using mobile phones to raise awareness among clinicians, patients and nurses. Those sorts of areas of research are really

important and need to be expanded. Probably the time is right for another joint funding venture in this area.

Professor Threlfall: I am fully in support of what has been said. I mentioned the bioinformatics initiative. It is quite important to develop these areas. Maybe more quantitative risk assessments should be done in the research in that area to see how different controls have been effective, and which controls could be dumped, for want of a better word, or taken forward. Risk assessment of different controls and whether or not they have worked is an area that has been somewhat lacking in the past.

Q35 Pamela Nash: That is really helpful. It is good to hear that we have centres of excellence in the UK. Obviously, as a Committee we are concerned about where there appear to be gaps. Professor Piddock, you mentioned your concerns about lack of funding. Are you aware of the Catapult system—the new technology and innovation centres in the UK, which aim to support ideas and research and get products on to the market? Is this an area that would benefit from having a Catapult and that extra support?

Professor Piddock: Yes, definitely. All areas of research, from very basic to translational and clinical research, need additional funding. Use of antibiotics underpins all areas of medicine, and it will affect everybody if we do not start to resolve this. Increasing funding across the piece will be most welcome.

Q36 Pamela Nash: Why does there appear to be market failure in this area of research? Why are pharmaceutical companies not falling over themselves a bit more to invest in something that will be one of the biggest products of the future, if they succeed in creating it?

Professor Piddock: There are many reasons, as I am sure you are aware, not least the fact that many pharmaceutical companies have merged and become few. The few that are left decided that the return on investment in this therapeutic area did not match that for other therapeutic areas. There are the technical challenges in going from discovery to development and clinical trials. When you do a clinical trial for an antibacterial drug it is not the same as, say, a breast cancer drug. You know that every patient in a breast cancer trial has breast cancer. You also have several weeks in which to diagnose them accurately and do personalised medicine, making sure the treatment is right for them. We just do not have that with bacterial infections. If a patient with a serious infection—say, sepsis—is admitted to hospital, you have to treat them straight away, as Sharon said earlier. For clinical trials, they would have to recruit hundreds of patients to get the few they needed with the infection they are really developing a drug for. If you are trying to develop a pneumonia drug, many pathogens can give pneumonia. It is not like breast cancer. If you are developing an antibiotic, you are developing a drug to work at multiple body sites, and all the issues associated with that. It is technically challenging, and it was perceived as lack of return on investment.

By breaking down that pipeline of discovery, research and development, there have been some major advances, as I am sure you are aware. There was a recent meeting at Chatham House discussing in particular what to do with new antibiotics when they were developed. How are we going to make them available in both high-income and low-income countries, so there is equitable access? We are starting to grapple with these issues. Are these going

to be available for everybody to use, wherever they are? One drug company in particular said that they would not develop antibacterials in the future for use in animals.

This is starting to be tackled. There are now issues about the way clinical trials are being designed, trying to encourage diagnostic companies to become much more active in this area, linking in with pharmaceutical companies who are active in discovery, research and development.

Professor Peacock: Your question was about why people were not leaping to develop drugs. It is about the cost of development and the return, but that equation is a weak one. Traditionally, we have not paid a lot for our antibiotics. Some of the off-patent antibiotics are very cheap. If we do not charge as much for a new antibiotic as a cancer drug, it is not such an attractive thing to produce. Perhaps we need to be thinking about pricing antibiotics differently from the way we used to, changing our mindset about those people who can afford to pay. We could consider these to be as valuable as an anti-cancer drug and charge more.

There are other issues—for example, regulation. I understand that regulatory issues can slow down the process of getting a drug to market. When you put all these things together—the likelihood of a return, the probability that emergence will rise in the end and the regulatory issues—they all stack up as disincentives. It is a matter of getting rid of those disincentives.

Professor Piddock: The discussion at the Chatham House meeting, the report of which is freely available on its website, was about how to stimulate making new drugs and valuing them in society. Is "value" a monetary value? We do not value them; we expect to get them. Because they are such successful drugs, and they have saved millions of lives, we do not value them in the same way; we expect to get them. We also use antibacterial compounds in the home: they are in toothpaste and washing-up liquids. We should be saying, "We're not going to use these compounds everywhere; we are going to have them just in human medicine," and look to get rid of bacteria that colonise or infect other areas in different ways.

Q37 Pamela Nash: You have talked about the money gap. Is there a gap in the UK in terms of the skills we need to do the correct research to tackle this problem?

Dr Goodwin: Potentially we are in danger of losing a lot of our microbiological skills, because microbiology is disappearing from a lot of undergraduate syllabuses and the practical elements are being taken out. There is a great danger.

Professor Piddock: There is a danger both in the science base and also in clinical areas. For instance, it is BSAC's understanding that many hospitals are finding great difficulty in appointing microbiologists who give specialist advice and support in this area, and are able to understand antimicrobial resistance and the drugs that should be used. We are not producing as many microbiologists as are needed. That has also led to centralisation of facilities. We are just not getting the support.

Q38 Pamela Nash: Is it because the right courses and training are not available to people, or because people are not attracted to those vocations or careers any more?

> ***Professor Piddock***: I think people are attracted to microbiology, in the same way as they are attracted to other key areas of medicine. They are particularly attracted to antimicrobial resistance and treating infections, but it is an under-resourced area right the way through. It is under-resourced in terms of how much we teach and how much research we do, and therefore how many PhD students there are and how we train them, and how many clinical fellows there are. There are just not enough to play to our strengths in the UK.

Chair: We have covered an awful lot of ground this morning. I am conscious that I cut you off when you wanted to develop some of the answers. If when you see the transcript, there is further information you would like to add to your evidence, I would be extremely grateful if you would drop us a note. Thank you very much for your attendance this morning. It was very interesting.