Fitting the message to the location: engaging adults with antimicrobial resistance in a World War 2 air raid shelter

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Running header: Engaging adults, AMR and WW2

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Abstract

Aims

There are many different initiatives, global and local, designed to raise awareness of antimicrobial resistance (AMR) and change audience behaviour. However, it is not possible to assess the impact of specific, small-scale events on national and international outcomes - although one might acknowledge some contribution to the individual and collective knowledge and experience-focused 'science capital' As with any research, in preparation for a public engagement event, it is important to identify aims, and appropriate methods whose results might help satisfy those aims. Therefore, the aim of this paper was to develop, deliver and evaluate an event designed to engage an adult audience with AMR.

Methods and Results

The venue was a World War 2 air raid shelter, enabling comparison of the pre- and post-antibiotic eras via three different activity stations, focusing on nursing, the search for new antibiotics, and investigations into novel antimicrobials. The use of observers released the presenters from evaluation duties, enabling them to focus on their specific activities. Qualitative measures of audience engagement were combined with quantitative data.

Conclusions

The evaluation revealed that adult audiences can easily be absorbed into an activity- particularly if hands-on - after a brief introduction.

Significance and Impact of Study

This research demonstrates that hands-on practical engagement with AMR can enable high level interaction and learning in an informal and enjoyable environment.

Keywords

- Antibiotics
- Bacteriophages

- Biofilms
- Soil
- Resistance
- Adult Education
- Outreach
- Public Engagement

56 **Introduction**

57 Antimicrobial resistance (AMR) is recognised as a global issue. There are several international
58 initiatives designed to raise awareness and change behaviours of a range of stakeholders within
59 pharma, agriculture, the medical, midwifery and nursing professions (WAAR, WHO) and the public
60 (WAAW, Antibiotic Guardians). Others encourage researchers to address the challenges of diagnosis
61 and discovery of new agents (https://longitudeprize.org/), to apply for focused funding (Kelly,
62 Zoubiane et al. 2016) and to work with politicians and policy makers (egLeSPAR
63 [www.bsac.org.uk/learned-societies-partnership-on-antimicrobial-resistance-lespar/]) .
64 Children are the target audience for games such as e-bug (McNulty 2011), plays
65 (https://www.microbiologysociety.org/event/education-outreach-events/stopping-the-spread-of-
66 superbugs-2012.html) and hands-on activities such as the Small Worlds Initiative (Davis, Sloan et al.
67 2017) and Antibiotics Unearthed (https://www.microbiologysociety.org/education-
68 outreach/antibiotics-unearthed.html). At family-focused events, adults tend to work with the
69 scientists to engage their own children. Adults can also access public information through television
70 and poster advertisements, events (eg science cafes), the news and other media (for example the
71 television documentary Michael Mosley versus the Superbugs, www.bbc.co.uk, screened on 17 May
72 2017) and the BBC Radio 4 series Resistance by Val McDiarmid, first aired on 3 March 2017
73 [`www.antibioticresearch.org.uk]), and participate in citizen science projects such as Swab and Send
74 (https://www.facebook.com/swabandsend/). However, active engagement is less of a priority when
75 adults are the intended audience.
76 Evidence for the success of campaigns and initiatives might be deduced from such newsworthy
77 successes as the reduction in prescriptions for antibiotics (Wise 2016), or the decrease in MRSA
78 infections (Duerden, Fry et al. 2015), but the impact of specific events on such outcomes is not easy
79 to assess – although one might acknowledge some contribution to the individual and collective
80 'science capital' which has been used to describe a measure of engagement with science
81 (www.kcl.ac/uk and www.transformingpractice.sciencemuseum.org.uk). It is important to make

critical evaluations of such events in order to inform and enhance any future activities. Quantitative data demonstrate reach (for example how many attended, how many participated). Other feedback sought at events tends to reveal that events are 'interesting, informative and enjoyable' (Verran et al., 2018; Redfern et al, 2018), rather than providing any critical or constructive comment. Even if asked to name 'three things you have learned', or similar, data acquired are still essentially quantitative/fact-based (Redfern et al. 2015). Evidence of impact of an activity on the audience requires more qualitative, descriptive evaluation around engagement and perception (for example, how do you feel about this, what are your thoughts?).

In a previous family-focused event designed to raise awareness of AMR, it was apparent that adults were keen to engage researchers in conversation, but their prime focus was the entertainment of their children (Redfern et al., 2018). As noted above, events are rarely designed to allow adults to get hands-on experience of laboratory science, in an in informal environment with scientists. Therefore the aim of this paper was to develop, deliver and evaluate an event designed to engage an adult audience with AMR.

Materials and methods

Event venue

Stockport air raid shelters (https://www.stockport.gov.uk/topic/air-raid-shelters) are tunnels cut into the red sandstone cliffs that frame the Mersey valley which runs through the town. One of the tunnel networks is open to the public as a tourist attraction. Comprising almost one mile of tunnels, the site has capacity for over 6000 people to take shelter during air raids, but for conducted tours today, numbers are limited.The tunnels contain a range of real and replica ephemera, including toilets (not for use), a nursing station, an area for feeding mothers, a catering station, and racks of metal frames of bunk beds. There is also a blackout room, and a separate area where visitors gather prior to their conducted tour.

Stockport tunnels provided an ideal opportunity to explore AMR with an adult audience by revisiting the pre-antibiotic era (penicillin was made available for the troops fighting the Second World War, but because it was in short supply, it was not available for the civilian population, except in very rare circumstances as a 'corpse-raising drug' (Brooks, 2018)), and considering a 'post-antibiotic era. The event was held as part of the 2017 Manchester Science Festival (http://www.manchestersciencefestival.com/).

Planning and delivery: *Key messages*

The team leaders (JV and JR) identified a series of questions for the audience that would frame the event. These were:

How important are antibiotics to us today?

How did we cope without them?

Can we find new antibiotics?

Can we develop alternatives to antibiotics?

Why is AMR an issue and what is being done to address it?

The full delivery team then identified activities that would engage the adult audience whilst addressing these questions.

How important are antibiotics to us today?

Audience members assembled in the meeting space (a tunnel with bench seating on either side, period posters and bunting), and were introduced to the museum, to AMR and the event by the lead author and the museum curator (fig 1). They were each provided with a 'gingerbread man' diagram (and a pen) and asked to mark areas of the body for which they had taken antibiotics (anonymously). The aim of this activity was to encourage reflection on the value of antibiotics in the treatment of

133 both superficial and systemic infection. The audience was divided into groups of ten, and each group
134 was led into the tunnels proper by a guide. The diagrams were collected and data were pooled onto
135 a larger 'gingerbread man' for viewing in the museum shop after the event. Leaflets encouraging
136 sign up to the Antibiotic Guardian scheme (http://antibioticguardian.com/) were also distributed,
137 along with information about the museum itself.
138
139 *How did we cope without them?*
140 At the tunnel nursing station, the groups listened to stories about the pre-antibiotic era, and the role
141 of nurses in the treatment of infections and disease. Penicillin was seen as a miracle cure, as soldiers
142 who previously could have succumbed to gangrene had their limbs saved, and were returned to
143 battle. Penicillin was also invaluable against venereal disease (Bud, 2007; Harrison, 2004). Initially
144 nurses thought that penicillin would make their expertise in infection management almost obsolete,
145 but the involvement of nursing staff in the experimental stages of the introduction of a new
146 technology was a new venture: nurses learnt alongside their medical colleagues, shifting boundaries
147 between nursing and medical work and at times dispelling long-held professional hierarchies. The
148 need for nurses to administer penicillin (intramuscular injections three hourly into the buttock for up
149 to five days) also meant that they were needed at the frontline (Brooks, 2018)
150
151 *Can we find new antibiotics?*
152 The canteen area was ideal for some practical microbiology experiments, providing table surfaces to
153 facilitate activities. In an introduction, visitors were shown a timeline adapted from Lewis (2013)
154 revealing intensive activity over a relatively short time period when the majority of antibiotics were
155 discovered and mass-produced. Now there are many initiatives whose aim is to identify potential
156 new agents, with samples being taken from different environments for example caves (Pawlowski,
157 Wang et al. 2016), the depths of the ocean (Zhang, Dong et al. 2017) and everyday sites (for example
158 Swab and Send) and the Small World Initiative. After this introduction, visitors swabbed sites in the

159 tunnels in a search for antibiotic-producing microorganisms. Each visitor was provided with a
160 moistened swab (only the presenter/demonstrator had access to liquid in the tunnel to minimise
161 spillage risk) which they used to spread inoculate a malt extract agar and a tryptone soy agar plate
162 (Oxoid, Basingstoke). Each plate was marked, and after incubation at the University (ten days at 30C
163 to ensure sufficient mould growth), photographs were posted on FlickR
164 (https://flic.kr/s/aHsm5QBJR1) for viewing and download. Visitors were also asked to select the
165 names of bacteria that they had heard of before the event from the list of WHO priority pathogens
166 for new antibiotic research and development (WHO 2017).
167
168 *Can we develop alternatives to antibiotics?*
169 This station, using the blackout facility, provided an opportunity for researchers to describe some of
170 their relevant work (https://www2.mmu.ac.uk/shs/research/microbiology/). From a range of topics
171 including phage therapy (e.g. Alves, Gaudion et al. 2014), repurposing of anti-cancer and other drugs
172 (e.g. Southam, Butler et al. 2017), antimicrobial metals (e.g. Redfern, Goldyn et al. 2017), natural
173 antimicrobials such as essential oils (Kinninmonth, Liauw et al. 2013), graphene as a delivery tool
174 (Whitehead, Vaidya et al. 2017), antimicrobial surfaces and surface hygiene as strategies to reduce
175 cross-contamination and cross-infection (Fisher et al, 2014), and the particular problems posed by
176 biofilm in terms of antimicrobial resistance (Whitehead and Verran, 2015) , three were selected,
177 determined by staff availability. These were phage therapy, repurposing other drugs containing
178 antimicrobial metals, and the nature of biofilm.
179 To avoid a mini-lecture format, brief illustrative demonstrations were devised – using 3-D glasses to
180 view models of phage and biofilm, and bioluminescent bacteria (*Escherichia coli* strain DH5a
181 containing a pGLO vector (Bio-rad) expressing Green Fluorescent Protein (GFP) grown in Nutrient Broth
182 supplemented with 0.2% arabinose for GFP induction. Bacterial fluorescence was observed using UV
183 backlights.) to dramatically demonstrate zones of inhibition on agar plates (fig 2), and death (by
184 inactivation of a liquid culture with resultant loss of fluorescence) in the dark space.

Why is AMR an issue and what is being done to address it?

These messages were reinforced throughout the visit, through key points on posters displayed at the stations, and via the presenters and discussion. The Antibiotic Guardian leaflet summarises a range of key points and actions.

Legal requirements and costs

Costs for the event were met directly and indirectly by the University. In terms of personnel time, in addition to two site visits, several planning meetings were held at the University. At the event itself, four Professors, three lecturers, three postgraduates, two nurse observers, and one University coordinator were in attendance, alongside three volunteers from Manchester Science Festival and three members of staff from the museum. Post-event, time was also needed for photography of over sixty agar plates and posting to the FlickR site.

Equipment costs were small, comprising swabs and agar plates. Travel to and from the venue, parking and an evening meal for University staff was also met by the University.

Public Insurance liability was covered for University staff, and appropriate risk assessments were made for each activity. Key issues were the minimisation of liquid spillage risk (neither liquids nor food are permitted in the tunnels), and any potential infection hazard posed by live microorganisms. The GFP-engineered *E.coli* culture (biosafety level one) was only held by the microbiologists, agar plates were sealed, and a disinfecting agent was available in case of spillage. The tunnels themselves have visitor afety procedures in place. Ethical approval to undertake non-participant observation of the participant groups was obtained from the Faculty of Health, Psychology and Social Care ethics committee at Manchester Metropolitan University .

Logistics and promotion

The event was held as part of Manchester Science Festival 2017, and was advertised (over 18s only) on the festival website as well as on the museum website. The University also promoted it through social media. Attendees registered through Eventbrite, and each paid £10 (museum costs).

The minimum number of registrations required was 18. A maximum number of forty was identified, so that groups of ten, each with a guide, could visit the three stations (nursing, swabbing and antimicrobials; a fourth station was unrelated to the AMR topic). A circularroute around the tunnels was mapped so that each group encountered all stations and not other groups (to prevent crowding). The time spent at each station was limited to twenty minutes, after which time a whistle was blown and the groups moved on, led by their guides. The sequence of stations therefore varied for each group, but since each activity was free-standing, it was considered that this would not affect visitor experience. The small group size and careful event planning facilitated opportunity for questions and discussion. Indeed, the entire evening was designed to be interactive, informal and friendly. Whilst the location was a particular focus for this event, it is important to consider that event's such as this can be reproduced in any location. If a location with an interesting story/history is available, embedding this into the event may help provide a more well-rounded, engaging event, and can help tailor towards target age range.

Evaluation

There was opportunity for gathering quantitative evidence of engagement via numbers of gingerbread men diagrams handed in, number of agar plates used, and number of FlickR downloads. Presenters/demonstrators could give some qualitative feedback, but in order to enable them to focus entirely on delivery, additional routes were implemented. The guides were asked to note questions asked by their group at each station. In addition, an observer remained at each station, tasked with recording audience engagement at regular intervals (table 1). Each observer selected their own intervals: activity-focused or time-focused. Observers recorded the number of group

237 members who demonstrated disengagement, passive engagement, task-orientated engagement, or
238 epistemic engagement (developed from Sadler, Puig et al. 2011). Interest in the 'giant gingerbread
239 man' was also noted.
240
241 **Results**
242 Quantitative evaluation
243 The event sold out on Eventbrite. Thirty-seven adults attended the event, typically in pairs or family
244 groups (with adult children). Informal conversation at the shop revealed that several had wanted to
245 visit the museum previously, and this event had provided the trigger (several also expressed a desire
246 to come back). Thirty-five gingerbread men were handed in after the introduction, and the giant
247 gingerbread man presented with 141 marks indicating antibiotics usage, particularly at mouth, nose,
248 throat, lungs and lower torso (fig 3). Several of the visitors examined the figure, but counts were not
249 made.
250 Sixty-two agar plates were inoculated. The enthusiasm with which the adults scouted the tunnels for
251 exciting locations to swab was remarkable. Images of all plates were posted on FlickR, which was
252 accessed 57 times within one week of posting (and also accessed 22 times within one week of the
253 event before results were posted). In addition to the swabbed samples, settle plates had been set up
254 to demonstrate the extent of aerial contamination (the tunnels were cool, but the air was moist).
255 Plates generally revealed a wide range of different colony morphologies of bacteria and fungi,
256 although there was no evidence of antimicrobial activity. The survey of recognised pathogen names
257 revealed that the only bacterial pathogen visitors had not heard of was *Acinetobacter baumannii* (Fig
258 4). Of the remaining 12 strains, the most common was *E. coli* (with 16% of responses).
259
260 Qualitative observations
261 *Feedback from guides*

262 The guides noted questions asked by the groups (table 2). These revealed a high level of
263 engagement, curiosity and understanding. Informal comments from the guides noted that in
264 general, visitors were absorbed with the hands-on activity, completely engaged with the nursing
265 stories, but occasionally less confident around the more overt research-based science presented in
266 the antimicrobial session, where some terminology and abbreviations were not explained. There
267 was also less time available for questions in this session.

268 *Feedback from observers*

269 *Nursing station*

270 Observations were made every five minutes. The observer noted that 'the groups became more
271 interactive as the evening progressed, probably because they had gelled as a group. Questions were
272 insightful and there was engagement with the process right from the start'. In every case, the
273 engagement shifted from passive to epistemic after the first five minutes. Interactive behaviours
274 included eye contact with presenter and other group members, nodding, laughter, discussion and
275 debate.

276 *Swabbing station*

277 Observations were made once at the start of the session, once in the middle and once towards the
278 end. In all four iterations, the visitors progressed from task-orientated engagement through to
279 epistemic engagement, with the observer commenting on the level of ownership the visitors gained
280 when allowed to go and swab an area of the tunnel which they had identified. The observer also
281 noted audience fascination with the antibiotic timeline, and shock at the lack of recent antibiotic
282 drug development.

283 *Antimicrobials station*

284 Observations were noted at five points during the session (introduction, fluorescence,
285 bacteriophage, biofilm, examine liquid culture). Disengagement was noted during the introduction
286 for the second group, and during the bacteriophage and biofilm topics for the fourth group.

Otherwise the engagement was passive for the introduction, predominantly task-orientated for other activities, with some epistemic engagement for most of the research topics.

Discussion

Overall, quantitative and qualitative markers of engagement indicated that this was a successful event, appropriate to the audience satisfying the aims of the delivery team and providing additional benefits for stakeholders. For the venue, previous events have focused on the tunnels themselves, rather than using them as an environment for the delivery of another message. The tunnels deadened sound well, so there was no noise interference from the different stations, and the circular route planning worked well logistically. The museum staff were very positive about the event, and were inspired to investigate other similar activities.

The adult-only nature of the event meant that the audience was free to enjoy and explore the topics: questions were high level, and the interactions between presenters and audience was effective and informal. In particular, the storytelling element at the nursing station enabled humorous and relaxed interaction. Storytelling, if done well (and if not too long - particularly if the audience is standing) is an excellent lure to engagement and an increasingly popular means of engaging audiences with science (McDrury and Alterio, 2003). This event demonstrated that there is no age limit for such an approach. Indeed, literature itself provides an excellent facilitator for discussion between scientists and non-scientists: for example, the book of short stories commissioned by NESTA (https://www.nesta.org.uk/) to explore AMR (Infections Futures, https://www.nesta.org.uk/publications/longitude-prize-infectious-futures) was recently considered during a meeting of the Bad Bugs Bookclub (http://www2.mmu.ac.uk/engage/what-we-do/bad-bugs-bookclub/). Similarly, the swabbing exercise was exceptionally successful: the adults were as excited and enthralled as children to be doing some practical microbiology. ‘Doing’ and ‘creating’ is always most appropriate for high-level learning (e.g. Bloom’s taxonomy), and again, this approach

appears not to have any upper age boundary, and perhaps should be considered more regularly at adult-only events.

In terms of science-related findings, it was noted that the pattern of infections on the gingerbread man differed from that obtained at a previous family-focused event (Redfern et al., 2018): for the adults, fewer antibiotics were used for throat infections, but more for chest, UTI, knee, hand and foot infections. The simplicity of the gingerbread man outline prevented differentiation of infection of eyes, nose and mouth, genital/urinary, and breast/lungs. Nevertheless, the aim of this exercise was to demonstrate the value of antibiotics for commonly encountered infections (the opportunity was also provided to write if any systemic infections had been treated), and this aim was clearly met. The microorganism which was unknown to the audience was one of the three most critical on the WHO pathogen list. The other two 'critical' pathogens, *Pseudomonas aeruginosa* and *Klebsiella pneumoniae*, both scored the next lowest value with only 1.1% and 2.3% of responses.The most well-known pathogens were *E. coli* (16.2%), *Salmonella spp* (15.1%) and *S. aureus* (11.6%). This observation begs the question as to whether our audiences need to know such information, and if so, how is this information best conveyed.

The antimicrobials station provided a good opportunity for linking research and impact through a public engagement event, but it is important that presenters consider in advance the level of knowledge of their audience, as well as the particular messages they wish to convey. They should also ensure that there is opportunity for questions and audience engagement – whether hands-on or otherwise. There are many opportunities for science communication training in the UK (which could be considered by aspiring (and experienced) communicators.

This event was a first attempt to incorporate qualitative measures of audience engagement as an indicator of impact, coupled with quantitative data, as part of a highly focused event. The evaluation revealed that adult audiences can easily be absorbed into an activity after a brief introduction, enabling high level interaction and learning as well as enjoyment to take place. The use of observers released the presenters from evaluation duties, enabling them to focus on their specific activities.

Although a commonly used tool, a questionnaire was purposely not used to collect visitor feedback, as the team were concerned with 'questionnaire overload', and the appearance the the event 'success' was more important to the delivery team than the enjoyment and education of the visitors, instead opting for an unbiased view of engagement documented *in situ*. Another option, although not implemented in this study, is to attempt to re-engage the visitor at some point in the future to determine any longitudinal impact your event may have had.

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Conflict of interest

There are no conflicts of interest to report

357 References

358 Alves, D. R., A. Gaudion, J. E. Bean, P. Perez Esteban, T. C. Arnot, D. R. Harper, W. Kot, L. H. Hansen,
359 M. C. Enright and A. T. Jenkins (2014) Combined use of bacteriophage K and a novel bacteriophage
360 to reduce Staphylococcus aureus biofilm formation. *Appl Environ Microbiol* **80** (21): 6694-6703.
361 Brooks, J (forthcoming 2018). Negotiating Nursing: British Army Sisters and Soldiers in the Second
362 World War. Manchester, Manchester University Press.
363 Bud, R (2007) Penicillin: Triumph and Tragedy. Oxford, Oxford University Press.
364 Davis, E., T. Sloan, K. Aurelius, A. Barbour, E. Bodey, B. Clark, C. Dennis, R. Drown, M. Fleming, A.
365 Humbert, E. Glasgo, T. Kerns, K. Lingro, M. McMillin, A. Meyer, B. Pope, A. Stalevicz, B. Steffen, A.
366 Steindl, C. Williams, C. Wimberley, R. Zenas, K. Butela and H. Wildschutte (2017). Antibiotic discovery
367 throughout the Small World Initiative: A molecular strategy to identify biosynthetic gene clusters
368 involved in antagonistic activity. *MicrobiologyOpen* **6**(3): e00435-n/a.
369 Duerden, B., C. Fry, A. P. Johnson and M. H. Wilcox (2015). The Control of Methicillin-Resistant
370 Staphylococcus aureus Blood Stream Infections in England. *Open Forum Infectious Diseases* **2**(2):
371 ofv035.
372 Fisher L, Verran J, Kelly P, Ostovarpour S, Cooke K, Storgards E (2014) Molybdenum doped titanium
373 dioxide photocatalytic coatings for use as hygienic surfaces – the effect of soiling on antimicrobial
374 activity. *Biofouling*. **30**: 911-919.
375 Harrison, M (2004) Medicine and Victory: British Military Medicine in the Second World War. Oxford,
376 Oxford University Press.
377 Kelly, R., G. Zoubiane, D. Walsh, R. Ward and H. Goossens (2016). Public funding for research on
378 antibacterial resistance in the JPIAMR countries, the European Commission, and related European
379 Union agencies: a systematic observational analysis. *The Lancet Infectious Diseases* **16**(4): 431-440.
380 Kinninmonth, M. A., C. M. Liauw, J. Verran, R. Taylor, V. Edwards-Jones, D. Shaw and M. Webb
381 (2013). Investigation into the suitability of layered silicates as adsorption media for essential oils
382 using FTIR and GC–MS. *Applied Clay Science* **83-84**(Supplement C): 415-425.
383 Lewis, K. (2013). Platforms for antibiotic discovery. *Nat Rev Drug Discov* **12**(5): 371-387.
384 McDrury J and Alterio M (2003). Learning through storytelling in Higher Education using reflection
385 and experience to improve learning. Kogan Page Ltd. London.
386 McNulty (2011). Overview of e-Bug: an antibiotic and hygiene educational resource for schools. *J*
387 *Antimicrob Chemother* **66**(Suppl 5): V3-V12.
388 Pawlowski, A. C., W. Wang, K. Koteva, H. A. Barton, A. G. McArthur and G. D. Wright (2016). A
389 diverse intrinsic antibiotic resistome from a cave bacterium. *Nature Communications* **7**: 13803.

Redfern J, Burdass D, Verran J. 2013. Transforming a school learning exercise into a public engagement event: the good the bad and the algae. J Biol Ed 47(4): 246-252.

Redfern, J., et al. (2015). "Developing microbiological learning materials for schools: best practice." FEMS Microbiology Letters **362**(6).

Redfern J, Bowater L, Crossley M and Verran J (2018). Spreading the message of antimicrobial resistance: Case studies exploring the development of a successful public engagement event FEMS Microbio Lett (submitted)

Redfern, J., K. Goldyn, J. Verran, R. Retoux, L. Tosheva and S. Mintova (2017). Application of Cu-FAU nanozeolites for decontamination of surfaces soiled with the ESKAPE pathogens. *Microporous and Mesoporous Materials* **253**: 233-238.

Sadler, T. D., A. Puig and B. K. Trutschel (2011). Laboratory instructional practices inventory: A tool for assessing the transformation of undergraduate laboratory instruction. *Journal of College Science Teaching* **41**(1): 25.

Southam, H. M., J. A. Butler, J. A. Chapman and R. K. Poole (2017). Chapter One - The Microbiology of Ruthenium Complexes. Advances in Microbial Physiology. R. K. Poole, Academic Press. **71**: 1-96.

Verran, J., et al. (2018). Refreshing the public appetite for 'good bacteria': menus made by microbes. *Journal of Biological Education*: 1-13.

Whitehead, K. A., M. Vaidya, C. M. Liauw, D. A. C. Brownson, P. Ramalingam, J. Kamieniak, S. J. Rowley-Neale, L. A. Tetlow, J. S. T. Wilson-Nieuwenhuis, D. Brown, A. J. McBain, J. Kulandaivel and C. E. Banks (2017). Antimicrobial activity of graphene oxide-metal hybrids. *Int Biodeter Biodeg* **123** (Supplement C): 182-190.

Whitehead KA and Verran (2015). Formation, architecthre and functionality of microbial biofilms in the food industry. *Current Opinions in Food Science* **2**: 84-91

WHO (2017). Global Priority List of Antibiotic-Resistant Bacteria to Guide Research, Discovery, and Development of New Antibiotics. E. Tacconelli and N. Magrini, WHO.

Wise, J. (2016). GPs achieve dramatic cut in antibiotic prescriptions. *BMJ* 353.

Zhang, H., M. Dong, J. Chen, H. Wang, K. Tenney and P. Crews (2017). Bioactive Secondary Metabolites from the Marine Sponge Genus Agelas. *Marine Drugs* **15**(11): 351.

Figure 1: Introduction to the event made by museum curator and delivery team leader

Figure 2: Zones of inhibition demonstrated using fluorescence for enhanced visibility in a darkened space

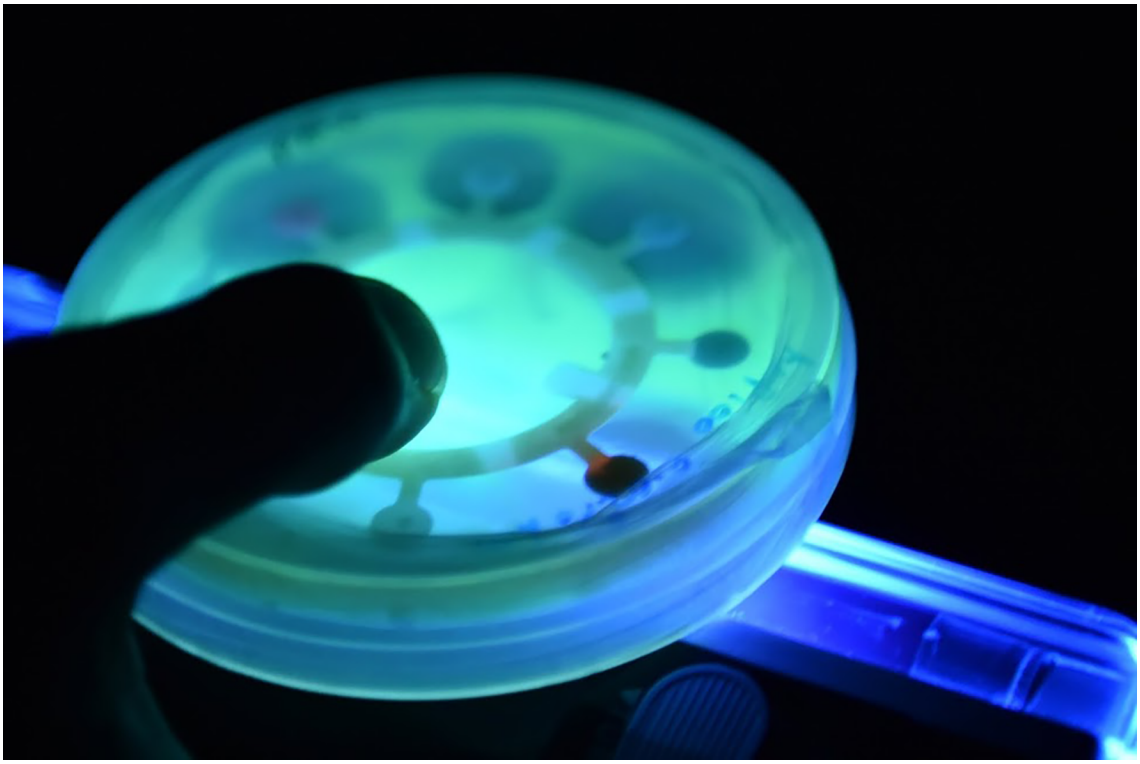


Figure 3: 'Gingerbread man' figure: each 'X' represents an infection for which one visitor was prescribed antibiotics. Most visitors had been prescribed antibiotics on several occasions.

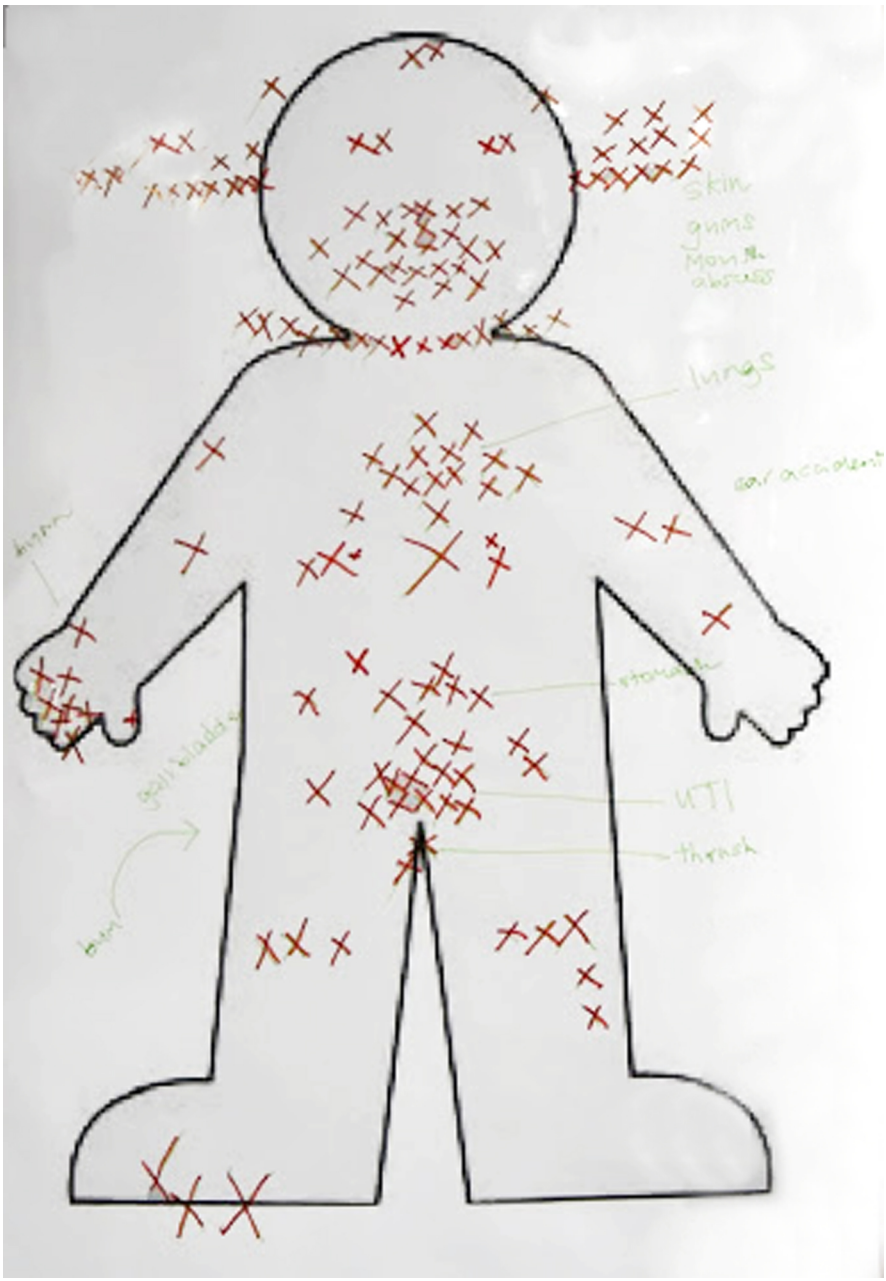
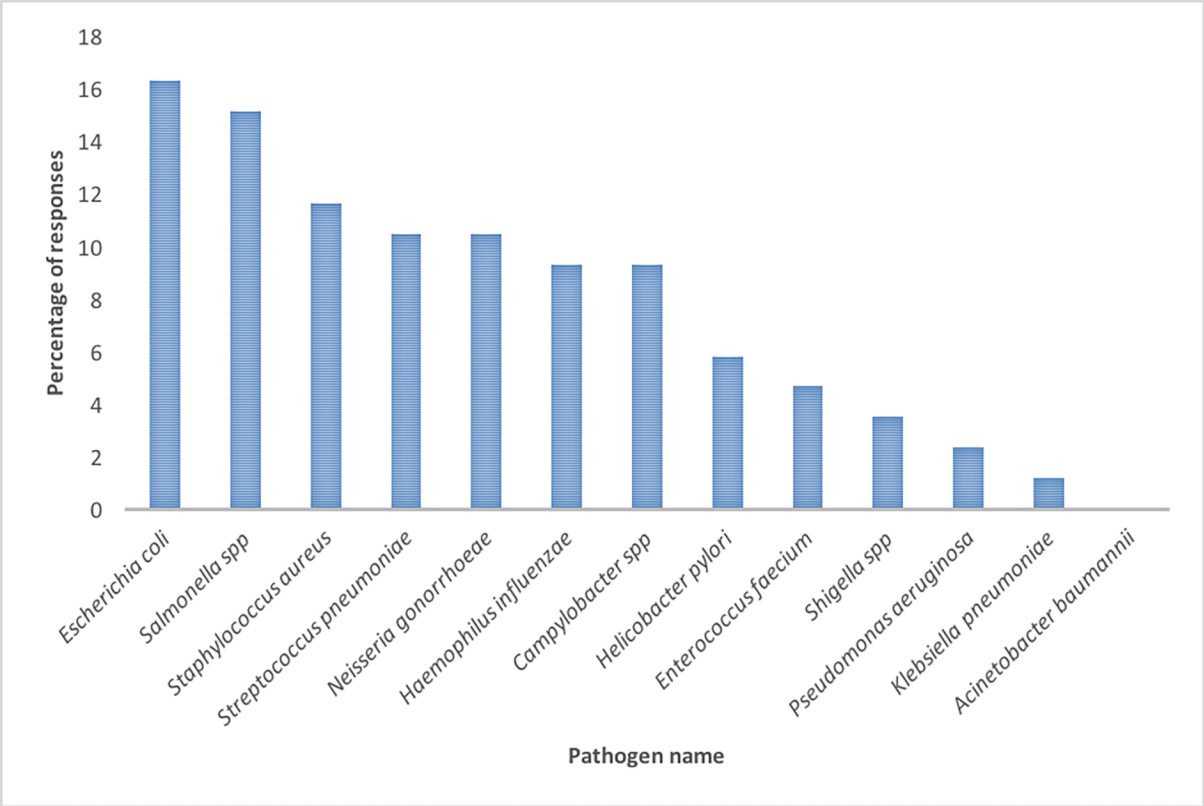


Figure 4: Percentage of responses given by visitors to the question 'which of the following pathogens have you heard of? (n=86)


18
16
14
12
10
8
6
4
2
0
Percentage of responses
Escherichia coli
Salmonella spp
Staphylococcus aureus
Streptococcus pneumoniae
Neisseria gonorrhoeae
Haemophilus influenzae
Campylobacter spp
Helicobacter pylori
Enterococcus faecium
Shigella spp
Pseudomonas aeruginosa
Klebsiella pneumoniae
Acinetobacter baumannii
Pathogen name

431

Table 1: Completed table provided to observers, describing behaviour that they were to note. This enabled them to create their own matrices, appropriate to their activity station.

Category	Description	Examples
Disengagement (DE)	Visitors are not focused	Visitors are discussing things not associated with the event. E.g. visitors are using a mobile phone.
Passive engagement (PE)	Visitors receive information	Visitors are paying attention to demonstrator/volunteer. E.g. Listening to instructions on activity.
Task-oriented engagement (TE)	Visitors are engaged in the event – guided by demonstrators	Visitors are actively involved / following a specified instruction from demonstrator.
Epistemic engagement (EE)	Visitors are actively involved in developing ideas and asking questions	Visitors are asking questions and actively involved in the development of research questions and hypotheses. Cognitively demanding.

437 Table 2: Questions asked by the audience at the different stations

438

Nursing	Antimicrobials	Swabbing
Was it only penicillin available during World War 2, or were any other antibiotics available?	How are those kind of drugs administered?	When we were young we didn't need hand gel.
If someone was at 'death's door', would antibiotics still have been effective?	Is resistance affected by metal export?	General questions around who owns/manages the database of bacteria compiled from swabs sent by the public, to be used for the detection of new antibiotics
Would antibiotics only have been made available for civilians if it was a last option/extreme situation? (question asked in context of military – including PoWs – being prioritised for antibiotics due to shortage of available supplies)	How close are you to getting there? (finding an alternative)	I notice mould grows really quickly on cream cheese – it tends to be pink coloured. I have heard that the pink mould is dangerous. Is that true?
It's interesting that antibiotics, during WW2, were considered a 'last resort' treatment, when they are now considered a first line of treatment (person commented that they are a teacher and lots of children are having antibiotics for minor ailments as parents have expectation of treatment from doctors).	How do you stop phage killing the bacteria you want?	General technical questions about swabbing (where to swab).
Did nurses/doctors observe penicillin allergies when penicillin first came into use?	Where do you get your bacteriophage from? Do you keep the samples?	
I use tea tree oil and find it stops most infectious in their tracks, so never get to the point where I need a prescribed antibiotic – will we be exploring natural alternatives to antibiotics during this event?	Do you think that people will accept these alternatives?	
When was penicillin/antibiotic resistance first noted?	Do you look at phage DNA?	
How did penicillin start getting exported around the world? Did we give it to the Soviets?		

439