Opinion Article

Synergizing Bacteriophage Therapy and Computational Neuroscience: A Ray of Hope in the Fight Against Antibiotic Resistance

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ABSTRACT

Antibiotic resistance presents an urgent and pervasive global health crisis that jeopardises human well-being. This dilemma primarily arises from the inappropriate and excessive use of antibiotics across diverse sectors, leading to the emergence of bacteria that have developed resistance to multiple medications. It is a matter of utmost concern due to its direct link to increased mortality rates and the disconcerting possibility of reverting to an era where antibiotics lose their effectiveness. This student experience paper delves into the potential of bacteriophage therapy as a remedy for antibiotic-resistant infections, a pressing issue emphasized by the National Health Service (NHS) in England. Building upon the recent first-hand experience of the first author while shadowing a General Medical Practitioner in Birmingham, UK, the study delves into critical facets of phage therapy. This exploration encompasses phage selection, formulation, delivery, and safety considerations. It also highlights the convergence with computational neuroscience, emphasizing the pivotal role of computational models in comprehending bacterial infections, antibiotic resistance, and neurological responses. This interdisciplinary approach underscores the necessity for collaborative efforts among microbiologists, healthcare professionals, and computational neuroscientists in addressing global healthcare challenges. Additionally, this experience sheds light on the practice of using antibiotics without a prescription, often for the treatment of infections that do not necessitate antibiotic intervention. This observation underscores the urgent requirement for stricter regulatory controls and an extensive educational program, both at the national and global levels.

Keywords: bacteriophage, antibiotics, British National Health Service, computational biology, interdisciplinary study

1. THE EXPERIENCE

As we progress deeper into the 21st century, the promise of bacteriophages in combatting bacterial infections becomes increasingly evident. Ongoing research and advancements in biotechnology fuel a sense of optimism regarding the potentially pivotal role of bacteriophage therapy in shaping the future of healthcare. Bacteriophages, often referred to as phages, possess a unique adaptability that allows them to evolve alongside bacterial pathogens. This adaptability leads to a continuously tailored approach to treatment, a dynamic feature conspicuously absent in conventional antibiotic therapies. Furthermore, the integration of artificial intelligence and machine learning into phage selection processes holds the tantalizing prospect of swiftly identifying the most suitable phages for specific infections, ushering in an era of precision medicine in our ongoing battle against bacterial diseases.

Phages, specialized viruses exclusively infecting and replicating within bacterial cells [1], form a diverse global array. Nonetheless, they share fundamental characteristics, notably their genetic material housed within an icosahedral capsid [2]. Remarkably, phages exhibit a high degree of species-specificity, typically targeting specific bacterial species or even particular strains within a species [3]. Phage therapy effectively capitalizes on this specificity, outperforming traditional bacterial treatment methods like antibiotics, surgery, or probiotics [4]. A significant advantage of phage therapy lies in its capacity for auto-dosing, where phages replicate during treatment, ensuring efficacy against both antibiotic-sensitive and antibiotic-resistant bacterial strains. In stark contrast to antibiotics, which have inadvertently fostered drug-resistant bacterial strains [5-6], bacteriophages offer the potential for targeted therapy with minimal harm to healthy human cells.

The application of phage therapy in countries grappling with antibiotic-resistant bacteria, such as Methicillin-resistant Staphylococcus aureus (MRSA) in the USA and Singapore, and more recently in the UK holds great promise for addressing resistant bacterial strains [7]. A successful case in California demonstrated the efficacy of bacteriophages against antibiotic-resistant Acinetobacter baumannii in a 68-year-old patient [8]. Nevertheless, the journey of phage therapy presents significant challenges to the scientific community. Existing regulations for pharmaceutical products lack specific guidelines for phage manufacturing, giving rise to concerns regarding quality control [9]. Phage delivery methods span a broad spectrum, ranging from oral suspension to advanced nanotechnology-based systems with formulations showing potential for long-term phage stability and efficacy [10].

Despite the immense potential of bacteriophage therapy, it is imperative to acknowledge the obstacles that lie ahead. Collaborative efforts among scientists, clinicians, regulatory bodies, and pharmaceutical companies are essential for overcoming the current challenges associated with phage therapy, as shown in Figure 1.

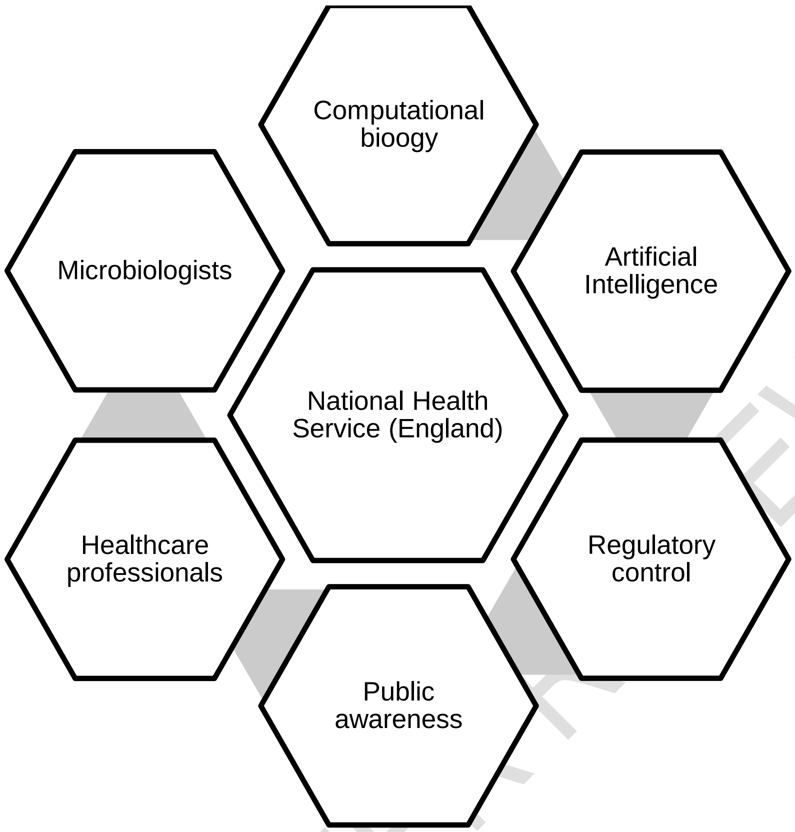

Fig. 1. Six Interdisciplinary Aspects to Address the Fight Against Antibiotic

Standardizing manufacturing protocols, conducting rigorous safety assessments, and establishing well-defined regulatory frameworks are vital to ensure phage-based therapeutics' reliable production and delivery. International cooperation can facilitate the exchange of knowledge and resources, fostering a global community dedicated to advancing phage therapy. By collectively addressing these challenges, we can unlock the full potential of bacteriophages and pave the way for a new era in the battle against bacterial infections and antibiotic resistance.

2. CONCLUSION

conclusion, the first authors' first-hand experience shadowing the General Practitioner Surgery within the National Health Service in England, coupled with extensive discussions with healthcare practitioners and managers, has left me firmly convinced of the indispensable role of bacteriophage therapy. It shines as a beacon of hope, offering precision-targeted treatment against specific bacterial strains and demonstrating remarkable efficacy against both antibiotic-sensitive and antibiotic-resistant bacteria. To fully unlock this potential, it's paramount that we foster a collaborative synergy between the realms of microbiology and computational neuroscience. While phage therapy holds immense promise, it calls for further research as an unwavering imperative. This research should not only fine-tune phage selection but also deepen our comprehension of diseases from both microbial and neurological angles. This interdisciplinary journey extends its reach into the convergence of drug-delivery nanosystems and computational neuroscience. It presents a pathway towards bolstering the long-term stability and overall effectiveness of phage therapy. Moreover, by incorporating principles from computational neuroscience into phage therapy, we envision a future where precise, personalized interventions against antibiotic resistance are not only envisioned but also guided by computational insights. Furthermore, this integration opens the door to harnessing the potential of artificial intelligence within the realm of computational neuroscience. The power of AI, combined with our evolving understanding of the human brain, holds tremendous promise for advancing phage therapy and our capacity to combat antibiotic-resistant infections. In light of certain misuse of antibiotics, tighter regulatory controls are urgently needed to curb unrestricted access to these medications. Simultaneously, a far-reaching educational program is imperative to raise awareness among the public, not only within the country but also globally. This collective effort brings us one step closer to a brighter healthcare future, where the convergence of biology, technology, and computational prowess propels us towards overcoming this looming medical threat of recent times.

REFERENCES

1. Abedon ST, García P, Mullany P, Aminov R. Editorial: Phage Therapy: Past, Present and Future. Front Microbiol. 2017; 15;8:981.
2. Carmody, C.M., Goddard, J.M. and Nugen, S.R. Bacteriophage Capsid Modification by Genetic and Chemical Methods. Bioconjugate Chemistry, 2021; 32(3): 466–481.
3. Kasman LM, Porter LD. Bacteriophages. 2022 Sep 26. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; 2023.
4. Principi N, Silvestri E, Esposito S. Advantages and Limitations of Bacteriophages for the Treatment of Bacterial Infections. Front Pharmacol. 2019; 8;10:513.
5. Loc-Carrillo C, Abedon ST. Pros and cons of phage therapy. Bacteriophage. 2011; 1(2):111-114.
6. Nasser A, Azizian R, Tabasi M, et al. Specification of Bacteriophage Isolated Against Clinical Methicillin-Resistant Staphylococcus Aureus. Osong Public Health Res Perspect. 2019; 0(1):20-24.
7. Suda T, Hanawa T, Tanaka M, et al. Modification of the immune response by bacteriophages alters methicillin-resistant Staphylococcus aureus infection. Sci Rep. 2022; 12:15656.
8. Schooley RT, Biswas B, Gill JJ, Hernandez-Morales A, et al. Development and Use of Personalized Bacteriophage-Based Therapeutic Cocktails To Treat a Patient with a Disseminated Resistant Acinetobacter baumannii Infection. Antimicrob Agents Chemother. 2017;61(10).
9. Pires DP, Costa AR, Pinto G, Meneses L, Azeredo J. Current challenges and future opportunities of phage therapy. FEMS Microbiol Rev. 2020;44(6).
10. National Institute of Biomedical Imaging and Bioengineering. Drug Delivery Systems. Available from [https://www.nibib.nih.gov/science-education/science-topics/drug-delivery-systems-getting-drugs-their-targets-controlled-manner]; updated [2022 July]; cited [2023 Oct 10].