Bakteriophagen – Therapie und CRISPR/Cas
Bacteriophages – Therapy and CRISPR/Cas

Agata Anna Cisek, Iwona Dąbrowska, Karolina Paulina Gregorczyk et al. (2017) **Phage Therapy in Bacterial Infections Treatment: One Hundred Years After the Discovery of Bacteriophages.** Curr Microbiol. 74(2), 277–283. Published online 2016 Nov 28. doi: 10.1007/s00284-016-1166-x PMCID: PMC5243869 PMID: 27896482

Chanishvili N (2018) **Early experience with phage therapy - ESCMID**
https://www.google.de/url?sa=t&rct=j&q=&esrc=s&source=web&cd=9&ved=2ahUKEwiv-ci4-ozeAhULyaQKHQTPCQsQFjAIegQIBRAC&url=https%3A%2F%2Fwww.escmid.org%2Fescmid_publications%2Fescmid_elibrary%2Fmaterial%2F%3Fmid%3D65029&usg=AOvVaw3K_UYEm0XhlaFFFzPXw-6o

d'Hérelle F (1917) Sur un microbe invisible antagoniste des bacilles dysentérique. Acad Sci Paris. 165, 373–5.

d'Hérelle F (1921) Le bacteriophage. La Nature (Paris) 49, 219–22

d'Hérelle F (1926) Le Bactériophage et Son Comportement. Paris et Cie

Rice TB (1930) Use of bacteriophage filtrates in treatment of conditions: Report of 300 cases. Am J Med Sci. 179, 345–60

Eaton MD, Bayne-Jones S (1934) Bacteriophage therapy. JAMA, 103, 1769-76, 1847-53, 1934-39.

D'Hérelle F. (1936) Traitement et prophylaxie par le bactériophage des maladies épidémiques de nature bactérienne. Le bactériophage. Applications thérapeutiques. La Médecine. 17(Suppl 2), 23–32.

d'Herelle F (1948/1949) Le bactériophage. Atomes, 3, 399-403. (Translated in Sci News, 14, 44-59, 1949.)

Hershey AD, Chase M (1952) Independent Functions of Viral Protein and Nucleic Acid in Growth of Bacteriophage. J Gen Physiol, 36, 39-56

Duckworth DH (1976) Who discovered bacteriophage? Bacteriol Rev, 40, 793–802

Botstein D (1980) A theory of modular evolution for bacteriophages. Ann N Y Acad Sci 354, 484-490.

Ioseliani GD, Meladze GD, Chkhetiia NS et al. (1980) **Use of bacteriophage and antibiotics for prevention of acute postoperative empyema in chronic suppurative lung diseases**. Grudn. Khir. (Rus)

Ackermann H-W, DuBow M. (1987) Practical Applications of Bacteriophages. Florida: CRC Press; Viruses of Prokaryotes I: General Properties of Bacteriophages.

Cisło M, Dabrowski M, Weber-Dabrowska B et al. (1987) **Bacteriophage treatment of suppurative skin infections**. Arch Immunol Ther Exp (Warsz) 35(2), 175-83
http://www.ncbi.nlm.nih.gov/pubmed/3447533

Bull JJ, Levin BR. (1996) Phage therapy revisited: The population biology of a bacterial infection and its treatment with bacteriophage and antibiotics. Am Nat. 147, 881–98

Merill CR et al. (1996) Long circulating bacteriophages as antibacterial agents. PNAS 93, 3188-3192

(1997) Phage - The Virus that Cures **Video**, 49 min. http://topdocumentaryfilms.com/phages-the-virus-that-cures/

Richardson JF, Rosdahl VT, van Leeuwen WJ et al. (1999 **Phages for methicillin-resistant Staphylococcus aureus: an international trial.** Epidemiol Infect. 122(2), 227–233.
PMCID: PMC2809610 http://www.ncbi.nlm.nih.gov/pmc/articles/PMC2809610/

Mathur MD, Mehndiratta PL (2000) **Characterization of methicillin resistant Staphylococcus aureus strains by a set of MRSA phages.** Indian J Med Res. 111, 77-80. http://www.ncbi.nlm.nih.gov/pubmed/10937382

Carlton RM (1999) **Phage therapy: past history and future prospects.** Arch. Immunol. Ther. Exp. 47(5), 267-74 http://www.ncbi.nlm.nih.gov/pubmed/10604231

Weber-Dabrowska B, Mulczyk M, Gorski A. (2000) Bacteriophage therapy of bacterial infections: An update of our institute's experience. Arch Immunol Ther Exp. 48, 547–51.

Summers WC (2001) **Bacteriophage therapy**. Ann Rev Microbiol. 55, 437–51. PubMed

Sulakvelidze A, Alavidze Z, Morris JG (2001) **Bacteriophage therapy.** Antimicrob Agents Chemother. 45, 649–59. PMC free article PubMed

Kono M, Hoshina S, Machida K (2004**) Phage set for methicillinresistant Staphylococcus aureus (MRSA) strains combined with the international phage typing set and the phages from coagulase-negative staphylococci**. http://www.jscm.org/journal/full/01402/014020092.pdf

Schoolnik GK, Summers WC, Watson JD (2004) Phage offer a real alternative. Nat Biotechnol. 22, 505–6. PubMed

Hänggi BJ (2004) Die Phagentherapie und das Problem der Verwirklichung. Inauguraldissertation, Universität Bern. http://www.stub.unibe.ch/download/eldiss/04haenggi_b.pdf

Thiel K (2004) Old dogma, new tricks—21st Century phage therapy. In: Nature Publishing Group (Hrsg.): Nature Biotechnology. 22(1), 31–36. PMID 14704699.

Nancy A. et al. (2005) The players in a mutualistic symbiosis: Insects, bacteria, viruses, and virulence genes. PNAS, 102, 6919-26

André M. et al. (2005) War is peace—dispatches from the bacterial and phage killing fields. Curr Opin Microbiol, 8, 488-94

Jones JB et al. (2007) Bacteriophages for plant disease control. Annu Rev Phytopathol, 45, 245-62

Fruciano E. (2007) Phage as an antimicrobial agent: d'Herelle's heretical theories and their role in the decline of phage prophylaxis in the West Can J Infect Dis Med Microbiol. 18(1), 19–26.

Miedzybrodzki R[1], Fortuna W, Weber-Dabrowska B, Górski A. (2009) A retrospective analysis of changes in inflammatory markers in patients treated with bacterial viruses, Clin Exp Med, 9, 303-12. http://www.ncbi.nlm.nih.gov/pubmed/19350363

Rhoads DD, Wolcott RD, Kuskowski MA et al. (2009) Bacteriophage therapy of venous leg ulcers in humans: Results of a Phase I safety trial. J Wound Care, 18, 237-38, 240-43. http://www.ncbi.nlm.nih.gov/pubmed/19661847

Willner D et al. (2010) Colloquium paper: Metagenomic detection of phage-encoded platelet-binding factors in the human oral cavity. PNAS, 108, 4547-53

Debarbieux L et al. (2010) Bacteriophages can treat and prevent Pseudomonas aeruginosa lung infections. J Infect Dis, 201, 1096-104

Colomer-Lluch M, Imamovic L, Jofre J, Muniesa M (2011) Bacteriophages Carrying Antibiotic Resistance Genes in Fecal Waste from Cattle, Pigs, and Poultry. Antimicrobial Agents and Chemotherapy, 55 (10), 4908 DOI: 10.1128/AAC.00535-11

Colomer-Lluch M, Muniesa JJM. (2011) Antibiotic Resistance Genes in the Bacteriophage DNA Fraction of Environmental Samples. PLoS ONE, 6 (3), e17549 DOI: 10.1371/journal.pone.0017549

Fancello L, Desnues C, Raoult D (2011) Bacteriophages and diffusion of genes encoding antimicrobial resistance in cystic fibrosis sputum microbiota. Antimicrob Chemother. 66(11), 2448-54.

Rolain JM, Fancello L, Desnues C, Raoult D (2011) Bacteriophages as vehicles of the resistome in cystic fibrosis. J Antimicrob Chemother. 66(11), 2444-7.

Ackermann HW (2011) The first phage electron micrographs. Bacteriophage, 1, 225-27

Abedon ST et al, (2011) Phage treatment of human infections. Bacteriophage, 1, 66-85.

Raack R. (2012) Phagentherapie. http://www.raack.de/phage/index.html

Youle M. et al. (2012) Scratching the surface of biology's dark matter. Viruses: Essential Agents of Life, ed. Günther Witzany (Springer Netherlands), 61-81

Swanson MM. et al. (2012) Novel bacteriophages containing a genome of another bacteriophage within their genomes. PLOS ONE, 7, e40683

Metcalf JA, Bordenstein SR (2012) **The complexity of virus systems: the case of endosymbionts**, Curr Opin Microbiol http://dx.doi.org/10.1016/ j.mib.2012.04.010 http://www.ncbi.nlm.nih.gov/pubmed/22609369

Snitkin ES et al. (2012) Tracking a hospital outbreak of carbapenem-resistant Klebsiella pneumoniae with whole-genome sequencing, Sci Transl Med, 4, 148ra116

Międzybrodzki R, Borysowski J, Weber-Dąbrowska B et al. (2012) Clinical aspects of phage therapy. Adv Virus Res, 83, 73-121 http://www.ncbi.nlm.nih.gov/pubmed/22748809

Brüssow H (2013) Bacteriophage–host interaction: From splendid isolation into a messy reality. Curr Opin Microbiol, doi:10.1016/j.mib.2013.04.007

Sheetal R et al. (2013) Antibiotic treatment expands the resistance reservoir and ecological network of the phage metagenome. Nature, doi:10.1038/nature12212

McCallin S. et al, (2013) Safety analysis of a Russian phage cocktail: From MetaGenomic analysis to oral application in healthy human subjects. Virology, 443, 187-96

Seed KD. et al. (2013) A bacteriophage encodes its own CRISPR/C as adaptive response to evade host innate immunity. Nature, 494, 489-91

Barr JJ, Auro R, Furlan M (2013) Bacteriophage adhering to mucus provide a non–host-derived immunity. PNAS. doi/10.1073/pnas.1305923110. http://www.pnas.org/content/early/2013/05/16/1305923110

Łusiak-Szelachowska M, Zaczek M, Weber-Dąbrowska B et al., (2014) Phage neutralization by sera of patients receiving phage therapy," Viral Immunol, 27, 295-304. http://www.ncbi.nlm.nih.gov/pubmed/24893003

Brown-Jaque M, Calero-Cáceres, Muniesa M (2015) Transfer of antibiotic-resistance genes via phage-related mobile elements. Plasmid. http://www.sciencedirect.com/science/article/pii/S0147619X15000116

Yosef I et al. (2015) Temperate and lytic bacteriophages programmed to sensitize and kill antibiotic-resistant bacteria. PNAS, doi:10.1073/pnas.1500107112. http://www.pnas.org/content/early/2015/05/14/1500107112

Barr JJ et al. (2015) Subdiffusive motion of bacteriophage in mucosal surfaces increases the frequency of bacterial encounters, PNAS, 112, 13675-80.

Hardes K, Köhler SM, Beyer, W et al. (2015) **Novel furin inhibitors with potent anti-infectious activity.** ChemMedChem. - Weinheim [u.a.] : Wiley-VCH, ISSN 1860-7187. 10(7), 1218-1231 http://www.ncbi.nlm.nih.gov/pubmed/25974265

Lekunberri I et al. (2016) **Exploring the contribution of bacteriophages to antibiotic resistance,** Environmental Pollution, doi:10.1016/j.envpol.2016.11.059.

Tetz GV, Ruggles KV, Zhou H et al. (2017) **Bacteriophages as potential new mammalian pathogens.** Scientific Reports **7**, Article number: 7043 Download Citation
„There was a reduction in the abundance of *Blautia, Catenibacterium, Lactobacillus*, and *Faecalibacterium* species and an increase in *Butyrivibrio, Oscillospira* and *Ruminococcus* after bacteriophage administration."

Brady TS, Merrill BD, Hilton JA, Payne AM, Stephenson MB, Hope S (2017) **Bacteriophages as an alternative to conventional antibiotic use for the prevention or treatment of Paenibacillus larvae in honeybee hives.** J Invertebr Pathol. 150:94-100. doi: 10.1016/j.jip.2017.09.010. Epub 2017 Sep 14 https://www.ncbi.nlm.nih.gov/pubmed/28917651

- **Leibnitz-Institut DSMZ-Deutsche Sammlung von Mikroorganismen und Zellkulturen GmbH** (2016) **Bakteriophagen und Phagentherapie.** https://www.dsmz.de/de/start/aktuelles/phagen-infoseite.html
- **Antibiotikaresistente Bakterien, antibiotic resistant bacteria** http://www.erlebnishaft.de/staphylococcusaureus.pdf
  - **Horizonaler Gentransfer** http://www.erlebnishaft.de/gentransfer.pdf

Bakteriophagen gewerblich
Bacteriophages commercial

COMPANY	LOCATION	PRODUCTS	APPLICATIONS	IN TRIALS?
AmpliPhi	Richmond, Virginia	Natural phage cocktails	**P. aeruginosa** lung infections in cystic fibrosis; **S. aureus** wound and skin infections; **C. difficile** gastrointestinal infect	Phase 1 approved November 2015
ContraFect Corporation	Yonkers, New York	Bacteriophage lysins	S. aureus bacteremia	Phase 1 launched April 2015
Pherecydes	Romainville, France	Natural phage cocktails	**E. coli and P. aeruginosa** burn and skin infections; **P. aeruginosa** respiratory infections; **S. aureus** bone/joint/prosthetic infect	Phase 1 launched September 2015
JSC Biopharm	Georgien	Natural phage coctails	See appropriate section	See appropriate section

AmpliPhi Biosciences Corporation (2019) Antibacterials; Bacteriophages AB SA01, Alternative Names: AB-SA01; AmpliPhage-002 https://adisinsight.springer.com/drugs/800044494
„AB-SA01 is a 3-phage investigational therapeutic being developed for treatment of MDR S. *aureus* infections. "

- **A sampling of firms that are conducting research on viral treatments for bacterial infections.** Selection above according to http://www.the-scientist.com/?articles.view/articleNo/44785/title/Viral-Soldiers/

➔ **Google search**
https://www.google.de/search?q=chronic+infections+and+bacteriophages+research+group&hl=de&btnG=Google+Search&gws_rd=ssl

Immunisierung von Bakterien gegen Phagen, Immunizing bacteria against phages. CRISPR/Cas, the Immune System of Bacteria and Archaea

„Die CRISPR/Cas-Methode (Clustered Regularly Interspaced Short Palindromic Repeats) ist eine biochemische Methode, um DNA gezielt zu schneiden und zu verändern (Genome Editing). Gene können mit dem CRISPR/Cas-System eingefügt, entfernt oder ausgeschaltet werden, Nukleotide in einem Gen können geändert werden“.
Quelle: https://de.wikipedia.org/wiki/CRISPR/Cas-Methode

"The CRISPR / Cas Method (Clustered Regularly Interspaced Short Palindromic Repeats) is a biochemical method for targeted DNA cutting and modification (genome editing). Genes can be inserted, deleted, or eliminated using the CRISPR / Cas system, nucleotides in a gene can be altered. "

Ishino Y, Shinagawa H, Makino K, Amemura M, Nakata A (1987) **Nucleotide sequence of the iap gene, responsible for alkaline phosphatase isozyme conversion in Escherichia coli, and identification of the gene product.** J Bacteriol 169, 5429–5433

Mójica FJ et al. (2005) Intervening sequences of regularly spaced prokaryotic repeats derive from foreign genetic elements. J Mol Evol, 60, 174-82.

Bolotin A et al. (2005) Clustered regularly interspaced short palindrome repeats (**CRISPRs**) have spacers of extrachromosomal origin. Microbiology, 151, 2551-61.

Barrangou R et al. (2007) **CRISPR** provides acquired resistance against viruses in prokaryotes. 315, 1709-12

Doudna J (2009) **Genome Engineering with CRISPR-Cas9**
https://www.youtube.com/watch?v=SuAxDVBt7kQ#t=64.724852

Horvath A, Barrangou R (2010) **CRISPR/Cas, the Immune System of Bacteria and Archaea**. Science 327, 167

Makarova KS et al. (2011) Evolution and classification of the **CRISPR-Cas systems**. Nat Rev Microbiol, 9:467-77.

Mina Rho, Yu-Wei Wu, Haixu Tang et al. (2012) **Diverse CRISPRs Evolving in Human Microbiomes.** PLOS Genetics 8(6), e1002441

Mali P, Yang L, Esvelt KM et al. (2013) **RNA-guided human genome engineering via Cas9.** Science (New York, N.Y.). 339(6121), 823–826, ISSN 1095-9203. doi:10.1126/science.1232033. PMID 23287722. PMC 3712628 (freier Volltext).

Seed et al. KD (2013) A bacteriophage encodes its own **CRISPR/Cas** adaptive response to evade host innate immunity," Nature, 494, 489-91.

Krupovic M et al. (2014) Casposons: a new superfamily of self-synthesizing DNA transposons at the origin of prokaryotic **CRISPR-Cas** immunity," BMC Biology, 12, 36.

Doudna J, Charpentier, E (2014) **The new frontier of genome engineering with CRISPR-Cas9**. Science 346(6213), 1077 doi:10.1126/science.1258096

Barrangou R, Marraffini LA (2014) **CRISPR-Cas** systems: Prokaryotes upgrade to adaptive immunity. Mol Cell, 54, 234-44.

Grens K (2015) **Dairy Engineering** How DuPont uses **CRISPR** to keep yogurt and cheeses safe from bacteriophage attack.
http://www.the-scientist.com//?articles.view/articleNo/41829/title/Dairy-Engineering/

Puping Liang P, Yanwen Xu Y, Xiya Zhang X et al. (2015) **CRISPR/Cas9-mediated gene editing in human tripronuclear zygotes.** Protein & Cell. 6, 363, doi:10.1007/s13238-015-0153-5.

Fulco CP et al. (2016) **Systematic mapping of functional enhancer-promoter connections with CRISPR interference.** Science, doi:10.1126/science.aag2445.

Sanjana NE et al. (2016) **High-resolution interrogation of functional elements in the noncoding genome.** Science, doi:10.1126/science.aaf8325.