LECTURE 14: Bacteriophages (Bacterial Viruses)

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Introduction

Bacteriophages are viruses that infect bacteria. Replicating within the bacterial cell, therefore they are **obligate parasites**. Infection with bacteriophages is restricted to particular strains within a single bacterial species. Phages exist in many forms and infect all living systems such as animals, plants, insects and bacteria, therefore phages are **ubiquitous in nature** and they have been shown to be found in soil and sediment.

Ecological Impact

- The death of the host cell results from the release of the progeny and replication of viral particles
- About **20-40% of marine bacteria every day** have been killed by bacteriophages
- They play important role in **bacterial evolution** and **ecological systems**
- Have a considerable role in **biogeochemical cycles** (carbon, nitrogen, sulfur and phosphorous cycles)

Composition

Nucleic Acid Properties

- Depending upon the phage, the nucleic acid can be either **DNA or RNA but not both**
- The nucleic acids of phages often contain **unusual or modified bases**, which protect phage nucleic acid from nucleases that break down host nucleic acids during phage infection
- **Simple phages** may have only **3-5 genes** while **complex phages** may have over **100 genes**
- The **majority of phages** contain **double strand DNA (dsDNA)**, while there are small phage groups with **ssRNA**, **dsRNA**, or **ssDNA**

Morphological Forms

There are **three morphological forms** of phages:

1. **Filamentous phages**
2. **Isosahedral phages without tails**
3. **Phages with tails**
4. Several phages with a **lipid-containing envelope** or contain lipids in the particle shell

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Bacteriophage Replication Cycle and Classification

Importance of Infection Cycle

The phage infection cycle is important when choosing a phage for antibacterial application. All known bacteriophages can be divided into **two groups** according to the type of infection:

1. Lytic Cycle (Virulent Phages)

- Characterized by a **lytic infection**
- Occurs when a host cell infected by virulent phage immediately begins to exploit the metabolic machinery of the cell
- Directs it towards replication of new virion particles in which the new phage DNA has been packaged and the protein capsid is fully formed
- **Phage-encoded proteins**, **holins** and **endolysins** work together to cause lysis of the cell
- Results in death of the host bacterial cell and the progeny are released
- New phages are released into the extracellular space

2. Lysogenic Cycle (Temperate Phages)

- A **temperate phage** has the ability to enter a lysogenic cycle
- The **phage DNA is integrated into the host genome**
- The DNA is replicated along with the host genome
- Such transition of viral DNA could take place through several generations of bacterium without major metabolic consequences
- Eventually the phage genes, at certain conditions impeding the bacterium state, will **revert to the lytic cycle**, leading to release of fully assembled phages

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Types of Viral Life Cycles

Classification Factors

The bacteriophages classification depends on several factors:

- **Host preference**
- **Viral morphology**
- **Genome type**
- **Auxiliary structures** such as tails or envelopes

Key Classification Features

- **Phage morphology** and **nucleic acid properties** are key classification factors
- The majority of phages contain **double strand DNA (dsDNA)**

- Small phage groups exist with **ssRNA**, **dsRNA**, or **ssDNA** (ss stands for single strand)

Morphological Groups

1. **Filamentous phages**
2. **Isosahedral phages without tails**
3. **Phages with tails**
4. Several phages with a **lipid-containing envelope** or contain lipids in the particle shell

Diversity

- This makes bacteriophages the **largest viral group in nature**
- More than **5500 bacterial viruses** have been examined in the electron microscope

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Phage Therapy

Definition

Phage therapy involves **clinical treatment of bacterial infections with phages (bacteriophages)**. The method, which has gained a renewed interest because of increasing frequency of infections by **multidrug-resistant bacteria**, has potential benefits.

Mechanism of Action

- Phages are **highly effective** in killing their targeted bacteria (their action is **bactericidal**)
- Phages may be considered as **good alternative** for patients allergic to antibiotics

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Phage Therapy Benefits

1. **Phages work against both treatable and antibiotic-resistant bacteria**
2. **They may be used alone or with antibiotics and other drugs**
3. **Phages multiply and increase in number by themselves during treatment** (only one dose may be needed)
4. **They only slightly disturb normal "good" bacteria in the body**
5. **Phages are natural and easy to find**
6. **They are not harmful (toxic) to the body**
7. **They are not toxic to animals, plants, and the environment**

Phage Therapy Disadvantages

1. **Phages are currently difficult to prepare for use in people and animals**

2. **It's not known what dose or amount of phages should be used**
3. **It's not known how long phage therapy may take to work**
4. **It may be difficult to find the exact phage needed to treat an infection**
5. **Phages may trigger the immune system to overreact or cause an imbalance**
6. **Some types of phages don't work as well as other kinds to treat bacterial infections**
7. **There may not be enough kinds of phages to treat all bacterial infections**
8. **Some phages may cause bacteria to become resistant**

Study Questions

Q1: Enumerate phage therapy benefits?

Answer: The benefits of phage therapy include:

- Effectiveness against both treatable and antibiotic-resistant bacteria
- Can be used alone or in combination with antibiotics and other drugs
- Self-replicating nature during treatment (potentially requiring only one dose)
- Minimal disturbance to normal beneficial bacteria
- Natural origin and ease of discovery
- Non-toxic to humans, animals, plants, and the environment
- Highly bactericidal action against targeted bacteria
- Suitable alternative for patients with antibiotic allergies

Q2: Define Bacteriophages

Answer: Bacteriophages are viruses that specifically infect bacteria. They are obligate parasites that replicate within bacterial cells and are restricted to particular strains within a single bacterial species. Phages are ubiquitous in nature, found in various environments including soil and sediment, and play crucial roles in bacterial evolution, ecological systems, and biogeochemical cycles.

End of Lecture

Dr. Ahmed Yaseen Abed