**Introduction:**
- Gram-positive, spore-forming microorganism
- At present three enterotoxins, able to cause the diarrheal syndrome:
  - Hemolysin BL (HBL), nonhemolytic enterotoxin (NHE) and cytotoxin K
  - HBL and NHE are three-component proteins
  - Cytotoxin K is a single protein toxin

**History**
- First discovered in 1880
- 1950 many outbreaks from meat and vegetable soups, cooked meat and poultry, fish, milk and ice cream were described in Europe
- In 1969, the first well-characterized *B. cereus* outbreak in the USA was documented

**Classification of *B. cereus***
- The genus *Bacillus* presently divided into subgroups based on spore morphology
- *B. cereus* falls in the *Bacillus subtilis* group, and it is closely related to *B. anthracis, B. mycoides* and *B. thuringiensis.*
- *B. cereus* and *B. anthracis* are both recognized as pathogens, but the former is implicated with foodborne disease. *B. anthracis* can infect perorally, but is inefficient.
Criteria to differentiate among four closely related Bacillus spp.

<table>
<thead>
<tr>
<th>Species</th>
<th>Colony</th>
<th>Motile</th>
<th>Hemolysis</th>
<th>Susceptibility to Penicillin</th>
<th>Parasporal Body</th>
<th>Virulent to Mice</th>
</tr>
</thead>
<tbody>
<tr>
<td>B. cereus</td>
<td>White</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>B. anthracis</td>
<td>White</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>B. mycoides</td>
<td>Rhizoid</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>B. thuringiensis</td>
<td>White/Grey</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
</tr>
</tbody>
</table>

Factors Affecting Growth of B. cereus

- Growth temperature 7-49°C with a minimum of 4-5°C, maximum 48-50°C
- Generally, spore germination temperature range from 8-30°C
- pH 4.9-9.3

Factors Affecting Growth of B. cereus

- Water activity 0.91-0.93
- Salt as high as 7.5% NaCl, some tolerate 10%
- D value for spores at 100°C around 3 min
- The dose for 90% reduction of spores is 1.25 - 4kGy
- 0.17-0.65 kGy for vegetative cells

Name of Illness Caused by B. cereus

- B. cereus has two recognized types of foodborne illness: diarrheal, emetic
- The emetic syndrome is caused by cereulide, a heat- and pH stable peptide toxin
- Consumption of food contaminated with this toxin may lead to emesis between 30 min and 5 h after ingestion

Name of Illness Caused by B. cereus

- The diarrheal syndrome is caused by enterotoxins that are produced during growth of B. cereus in the small intestine
- The diarrheal illness (more common in North America and Europe) is caused by a high molecular weight protein
- In some outbreaks there seems to be an overlap between the diarrheal and the emetic types of illness

Comparison of diarrheal and emetic types of B. cereus food poisoning

<table>
<thead>
<tr>
<th>Syndrome</th>
<th>Incubation</th>
<th>Duration</th>
<th>Dose</th>
<th>Foods</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diarrheal</td>
<td>8-16 h</td>
<td>12-24 h</td>
<td>10^1-10^7 CFU, ingested</td>
<td>Milk, soup, meat products, puddings</td>
</tr>
<tr>
<td>Emetic</td>
<td>1-5 h</td>
<td>12-24 h</td>
<td>10^6-10^9 per g of food</td>
<td>Rice, pasta, noodles, pastries</td>
</tr>
</tbody>
</table>

Which Food?

- Milk, vegetables, meat, and fish
- The emetic type of poisoning include rice products, potato, pasta, and cheese products

Which Food?

- Other foods such as sauces, pastries, soups, puddings, and salads were identified as vehicles in food poisoning outbreaks

Comparison of food poisoning caused by different bacterial agents.

<table>
<thead>
<tr>
<th>Pathogen</th>
<th>Incubation (h)</th>
<th>Duration of Illness, h</th>
<th>Dominating Signs</th>
<th>Type of Disease</th>
<th>Frequently Implicated Food</th>
</tr>
</thead>
<tbody>
<tr>
<td>B. cereus*, diarrohal</td>
<td>8-16</td>
<td>12-24</td>
<td>Diarrhea</td>
<td>toxic-infection</td>
<td>Meat products, soups, vegetables, puddings and sauces</td>
</tr>
<tr>
<td>C. perfringens</td>
<td>8-16</td>
<td>12-24</td>
<td>Diarrhea</td>
<td>toxic-infection</td>
<td>Meats, meat products, and gravy</td>
</tr>
<tr>
<td>B. cereus**, emetic</td>
<td>1-5</td>
<td>12-24</td>
<td>Diarrhea (fairly common) vomiting</td>
<td>Intoxication</td>
<td>Fried rice from Chinese restaurants and take out shops</td>
</tr>
<tr>
<td>S. aureus</td>
<td>1-5</td>
<td>12-24</td>
<td>Vomiting</td>
<td>Intoxication</td>
<td>Cooked meats and poultry and dairy products</td>
</tr>
</tbody>
</table>

Infective Dose

- Infective dose of *B. cereus* ranges from $10^4$ to $10^{11}$ cells per gram of food

Detection of *B. cereus*

- Blood agar can be used as a plating medium
- Nutrient broth followed by blood agar useful for most probable number count

Prevention:

- Preventing contamination of food with its spores is almost impossible
- Inhibit spore germination and prevent the growth of vegetative cells in cooked, ready-to-eat foods
**Prevention:**

- Temperatures under 100°C (212°F) might allow spore survival
- Non-refrigerated storage of foods and especially rice should be avoided
- Foods that require heating or cooling should undergo that process rapidly

Thank you!