Fire Blight of Pear and Apple
Causal agent: *Erwinia amylovora*

- *E. amylovora* native in N. America
- Hawthorne, mountain ash
- Apples, pears introduced by settlers

- Epidemic on pears in 1800-1900s

- Today pears still grown commercially west of Rockies due to bacterium but disease moved with pears
Fire Blight of Pear and Apple
Causal agent: *Erwinia amylovora*

First reported in 1794 in New York.

First disease where Koch’s postulates were fulfilled for plant bacterial pathogen.

-Thomas Burrill, at U. Illinois (1881)

-took 20 years of arguing to convince some scientists that bacteria could cause plant diseases.

First description of insect vector (honeybee) for bacterial disease.
Hopeful bulletin from the
Washington State
Agricultural Experiment
Station

February, 1915

FIRE BLIGHT
IS THE GREATEST DANGER TO THE FRUIT INDUSTRY

Blight is a PREVENTABLE Disease

Peach Blight, commonly called “Fire Blight,” is caused by microscopic, invisible
plaga (bacteria), growing inside the bark of the tree. No chemical has yet been found
which will kill these bacteria without killing the tree.

Blight is the “GREAT WHITE PLAGUE” of
the Fruit Industry

It causes losses of $25,000,000 annually to the country. If a disease could invade
the country and forward a tick of the amount, millions would be expended on our stars
to destroy it. If eight of greatinesse propagated our commerce, the sound of 45,000,000
per year, a serious matter would be required to be brought to control the fire.

ROUT THE ENEMY—BLIGHT—AT ALL COSTS!

THE DISEASE CAN BE
CONTROLLED
Inspection is Necessary
Give the Inspector Your Support.
Consult County Agricultural, State
Inspector, or Experiment Station for methods.
Write Experiment Station for Bulletin
on Blight.

Cleaning Up “HOLD-OVER” BLIGHT is the Best Means of Prevention
THE ONLY KNOWN WAY TO CONTROL BLIGHT IS BY SURGERY

In cutting it out, cut 6 to 24 inches below the cancer. DISINFECT TOOLS AND
CUTS WITH CORROSIVE SUBLIMATE.

Aphids, flies, ants, and other insects are important carriers of blight. Control these insects. Birds are
the natural enemies of insects. Protect the birds.

Inspect Nursery Stock carefully for blight. Avoid excessive watering of trees.

THERE IS NO PATENT CURE

BEWARE OF THE FAKE WITH THE “BLIGHT CURES.” Do not attempt to
cure blight by sprays, tree paint, inoculations, or said “doctoring.”

Blight fighting is a continuous matter. Organize and go after it. Winter is the best time to fight
the disease. NOW is the accepted time. Encourage your neighbors to clean up their orchards.

Eternal Vigilance is the Price of Clean Orchards
Fire Blight of pear, apple: *Erwinia amylovora*

Wilt, necrosis

Moves rapidly from vessels to other tissues, killing cells rapidly

Leaves killed too fast to form abscission layer and isolate pathogen
EPS (extrapolysaccharide) is an important virulence factor. Hrp pilus is present, along with effector proteins.
Disease development:
1. Epiphytic growth on stigmas
2. Movement down style to nectary
3. Movement to nectararthodes, colonization, entry
4. Rapid multiplication in intercellular spaces
5. Enter phloem, move to apical tissues
6. Enter xylem, move downward
7. Shoot blight, rootstock blight
8. Secondary infections from ooze: entry via stomates, lenticels, wind/hail and pruning wounds
Fire Blight of pear, apple:  *Erwinia amylovora*
Fire Blight of pear, apple: *Erwinia amylovora*

Dissemination:
Rain and insects

Blossom stage is key to control: keep populations on stigmas < $10^6$ cells/blossom

Shepherd’s crook
Fire blight epidemics are preceded by rain after warm periods during bloom: predictable

Models:
- Days above 15°C
- Rain events

Current models:
- COUGARBLIGHT - Washington
- MARYBLYT - Oregon
- Others (Israel, Billings...) – location alters effect of rainfall so must be accounted for in model (humid/arid climates)
Fire Blight of pear, apple: *Erwinia amylovora*

**Control:**

1. Resistant cultivars (Red Delicious) and rootstocks
2. Limit nitrogen
3. Prune all infections
4. Chemical controls
   1. Copper – not very effective
   2. Oxytetracycline (antibiotic) – no resistance but only ~50% reduction.
5. Biological controls
   
   Commercially available BlightBan (*P. fluorescens* A506); mix with antibiotics
Fire Blight of pear, apple: *Erwinia amylovora*

Pruning canker-infected branches in pear orchard
Fire Blight of pear, apple: *Erwinia amylovora*

Burning canker-infected branches in pear orchard
Fire Blight of pear, apple: *Erwinia amylovora*
Streptomycin resistance

Application of antibiotics to a pear orchard
Fire Blight of pear, apple: *Erwinia amylovora*

Streptomycin resistance

Antibiotic use in the United States in 1999 by crop$^a$

<table>
<thead>
<tr>
<th>Crop</th>
<th>Primary target</th>
<th>Antibiotic</th>
<th>No. states surveyed</th>
<th>Acreage treated (%)</th>
<th>Active ingredient used (lbs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Apple</td>
<td><em>Erwinia amylovora</em></td>
<td>Oxytetracycline</td>
<td>2</td>
<td>5</td>
<td>2,900</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Streptomycin</td>
<td>10</td>
<td>19</td>
<td>15,400</td>
</tr>
<tr>
<td>Peach, Nectarine</td>
<td><em>Xanthomonas arboricola</em></td>
<td>Oxytetracycline</td>
<td>3</td>
<td>8</td>
<td>6,900</td>
</tr>
<tr>
<td>Pear</td>
<td><em>Erwinia amylovora</em></td>
<td>Oxytetracycline</td>
<td>2</td>
<td>41</td>
<td>11,900</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Streptomycin</td>
<td>4</td>
<td>30</td>
<td>6,000</td>
</tr>
</tbody>
</table>

$^a$Data obtained from databases maintained by the USDA's National Agricultural Statistics Service (46).
Antibiotic resistance in agriculture:

**Streptomycin resistance:**

1. Ribosomal mutation; streptomycin can’t bind anymore (most common)

2. Inactivation by aminoglycoside phosphotransferase (encoded on plasmid of *E. amylovora*)

**Tetracycline resistance:** Rare so far, although certainly exists in nature. At least three different mechanisms:

1. Efflux pump
2. Ribosome mutation
3. Degrading enzyme
Biological control:

- *Pantoea agglomerans*, which produces an antibiotic that kills *Erwinia*

- Compete for iron (stigmas are iron limited)
Complete genome sequence and comparative analysis of the metabolically versatile *Pseudomonas putida* KT2440

Closely related to (85% genetic identity) this opportunistic pathogen *Pseudomonas aeruginosa* strain PAO1 6,264,404 bp
Toluene degradation by *P. putida* (monooxygenases)
TCE degradation

- **Anaerobic:** Reductive Dechlorination (converted to carbon dioxide by methanotrophic bacteria)

This makes sense – why use a difficult electron acceptor unless O2 is absent?

- **Aerobic:** co-metabolism (with phenol) by *P. putida*

*Co-metabolism - the transformation of a non-growth substrate in the obligate presence of a growth substrate or another transformable compound.*
*Pseudomonas putida* does these transformations via cometabolism; *Burkholderia* and methanotrophs to others.
GLYOXYLATE AND DICARBOXYLATE METABOLISM
Of 5420 putative ORFs, putative role assignments could be made for 3571 ORFs.
Genome analysis of KT2440 reveals extensive metabolic potential.

--mobile genetic elements are implicated – funky metabolism genes usually flanked by marks of horizontal transfer (36 transposons, 3 phages) in acquisition of such ORFs.

**ORFS found encoding enzymes for:**

--Degradation of aromatic substances (lignin derivatives, likely selected for decomposition of plant materials) into common intermediates of central pathways.

--Oxygenases that can potentially degrade “recalcitrant compounds” (chlorinated rings, alkanes, alkenes).

--more putative transporters for aromatic substrates than any currently sequenced microbial genome
Genome-Scale Reconstruction and Analysis of the *Pseudomonas putida* KT2440 Metabolic Network Facilitates Applications in Biotechnology


Figure 1. Schematic diagram of the metabolic reconstruction and analysis processes. Solid lines indicate consecutive steps of the reconstruction. Dashed lines represent information transfer. Dotted lines specify planned tasks. doi:10.1371/journal.pcbi.1000210.g001
Figure 4. Comparison of FVA calculations with $^{13}$C experimental flux data. The explanation of color codes is given in the figure. “?’” means that the reaction is not included in the particular metabolic network. Double-headed arrows depict reversible reactions, the bigger head shows direction of the positive flux.
doi:10.1371/journal.pcbi.1002310.g004
Phytoplankton blooms

“Give me half a tanker of iron, and I’ll give you an ice age.”

--the late John Martin, former director of the Moss Landing Marine Laboratory… in his best Dr. Strangelove accent.