I. History

A. Ancient history

- Sumerian clay tablet reference to plant disease 1700 BC. Vedic literature of India (1500 BC), literature of Aztec Maya and Incas references of potato disease, Theophrastus: Greek philosopher who recognized ~300 BC that wild trees were not liable to ravages of disease, whereas cultivated plants were subject to an array of devastating diseases.
- Roman rust god: In Roman mythology, Robigus ("wheat rust" or "mildew") was a fertility god who protected crops against diseases. He was worshipped alongside his sister Robigo for over 1700 years. His festival was the Robigalia on April 25. Worshipers would make offerings that were colored red, such as red wine or the sacrifice of red dogs, as this is the color of wheat rust.
- Biblical references to rusts, smuts and mildews.
- Biblical references in the bible: plague of the locust was one of the plagues of Egypt.
- Chinese and Arab literature of 1200 AD references to plant disease.
  - Middle ages-Renaissance
  - Diseases contribute to food famines of middle ages
  - Ergotism common in the middle ages. Ergotism is the effect of long-term ergot poisoning, traditionally due to the ingestion of the alkaloids produced by the Claviceps purpurea fungus which infects rye and other cereals, and more recently by the action of a number of ergoline-based drugs. It is also known as ergotoxicosis, ergot poisoning and Saint Anthony's Fire. Ergot poisoning is one of the explanations of bewitchment.
  - Due to the microscopic nature of plant pathogens, no progress was made in plant pathology until the invention of the microscope
  - Robert Hooke (1635-1703)-father of microscopy, publishes Micrographia (1665), coins the term “cell” to describe the basic unit of life.

B. Modern history

- The Great Famine was a period of mass starvation, disease and emigration in Ireland between 1845-1852 during which the island's population dropped by 20–25%. Approximately one million people died and a million more emigrated from Ireland. The proximate cause of famine was a potato disease commonly known as potato blight. Although blight ravaged potato crops throughout Europe during the 1840s, the impact and human cost in Ireland—where a third of the population was entirely dependent on the potato for food—was exacerbated by a host of political, social and economic factors which remain the subject of historical debate.
- Until the 1850s people clung to the notion of spontaneous generation i.e. people believed that pathogens were the outcome of disease and not its cause.
• Louis Pasteur (1822 –1895) was a French chemist and microbiologist born in Dole. He is best known for his remarkable breakthroughs in the causes and preventions of disease. His discoveries reduced mortality from puerperal fever, and he created the first vaccine for rabies. His experiments in 1860s supported the germ theory of disease because he discovered that microorganisms were present in the air (fermentation, using sterile broths and filters).

• Heinrich Anton de Bary (1831-1888) was a German surgeon, botanist, microbiologist, and mycologist. He is considered a founding father of plant pathology (phytopathology) as well as the founder of modern mycology. His extensive and careful studies of the life history of fungi and contribution to the understanding of algae and higher plants were landmarks of biology. He proved that pathogenic fungi were not the products of cell contents of the affected plants, and they did not arise from the secretion of the sick cells. In de Bary’s time, potato blight had caused sweeping crop devastation and economic loss. He studied the pathogen Peronospora infestans and made a great contribution by elucidating its life cycle. The origin of plant diseases was not known at that time. Much as Miles Joseph Berkeley (1803–1889) had insisted in 1841 that the fungus found in potato blight was the cause of diseases, de Bary declared that the rust and smut fungi were the causes of the pathological changes in disease plants. He concluded that Uredinales and Ustilaginales were parasites.

• Robert Hartig (1839-1901) is known as the Father of Forest Pathology. Through careful inoculations and observations, proved that Armillaria caused the disease and was not the result of “spontaneous generation.” They are shown in his best-known work, Wichtige Krankheiten der Waldbäume (1874), translated and published as Phytopathological Classic No. 12, Important Diseases of Forest Trees (1975).

• Herman Robert Koch (1843-1910) was a German physician. He became famous for isolating Bacillus anthracis (1877), the Tuberculosis bacillus (1882) and the Vibrio cholera (1883) and for his development of Koch's postulates. He was awarded the Nobel Prize in Physiology or Medicine for his tuberculosis findings in 1905. He is considered one of the founders of microbiology.

• During the last century many introduced pathogens have reached epidemic levels in North American forests causing huge economic losses and disrupting/altering ecosystems.

II. Symptoms of tree diseases as a reflection of disturbed physiological function (HO)

• Diseases can be abiotic or biotic
• Foliar diseases can disrupt photosynthesis and transpiration
• Pathogens that invade phloem interfere with its function
• Vascular wilt pathogens can survive in the vessels of sapwood xylem, disrupting translocation of water and causing wilt.
• Cankers can girdle kill the tree
• Heart and root rot fungi can utilize cell wall materials-disrupt root function, structural failure, reduced growth
• Shoot blights parasitize succulent growing tissues and flowers and can then persist as cankers
• Viruses and some bacteria can highjack the plants DNA replication mechanism and cause weird symptoms such as galls, chlorosis, rugosity and mosaic of leaves.

III. Essential plant pathology concepts
A. Introductory definitions-
   • Disease: is the deviation in the normal functioning of a plant caused by a persistent agent.
   • Diagnosis is the first challenge in addressing plant disease. Plant pathologists must be able to recognize the signs and symptoms of diseases.
   • Symptom: Is the expression of a disease by a plant as a response to the activities of a pathogen or another type of persistent agent. Symptoms may be localized or systemic (i.e. from slide: leaf spot and lesions fungus, canker, wilting, leaf spots bacteria, soft rot, ringspot by virus, flower break by virus)
   • Sign: Indication of disease from direct observation of a pathogen or its parts. (from slide: broom rape, dwarf mistletoe, bacterial ooze, smut, ergot sclerotium, powdery mildew spores and mycelia, nematodes).
   • Pathogen: A disease-producing organism or agent. Pathogens can be biotic, infectious, and transmittable, or abiotic, noninfectious and non-transmittable. Biotic plant pathogens: parasitic plants, fungi, oomycetes, viruses, bacteria, nematodes, phytoplasmas,
B. Disease triangle: disease is the result of the interaction of a susceptible host (plant), a virulent pathogen, and a favorable environment.
C. Koch’s postulates: Many diseases cause similar symptoms, therefore, it was necessary to develop a method to prove that an organism is the cause of a disease.
   1. The suspected pathogen must be consistently associated with diseased plants.
   2. The suspected pathogen must be isolated in a pure culture and its characteristics noted.
   3. The disease must be reproduced in a healthy plant inoculated with the isolated organism.
   4. The same pathogen characterized in step 2 must be isolated from the inoculated plant.
D. Lifestyles of pathogens:
   • Parasite: organism that lives in intimate association with another organism on which it depends for its nutrition; not necessarily a pathogen.
- **Biotrophs or obligate parasites**: organisms that can obtain nutrients only from living plant cells.
- **Saprophytes**: organisms that can obtain nutrients from dead organic matter
- **Facultative saprophytes**: are better adapted at living as parasites, but can survive as saprophytes if necessary.
- **Facultative parasites**: are primarily saprophytes, but can live as parasites if given the opportunity to invade compromised or senescing plant tissues.
- **Obligate parasites**: can only live on dead plant tissue, secondary invaders, cannot cause disease.
- Lifestyle of pathogen helps determine what kind of disease will occur.

<table>
<thead>
<tr>
<th>BIOTROPHS (obligate parasites)</th>
<th>NECROTROPHS (facultative parasites/facultative saprophytes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>★ have narrow host ranges</td>
<td>★ have wide host ranges</td>
</tr>
<tr>
<td>★ cannot grow as saprophytes</td>
<td>★ can grow as saprophytes</td>
</tr>
<tr>
<td>★ attack healthy host tissue at any stage</td>
<td>★ attack young, weak, or senescent tissues</td>
</tr>
<tr>
<td>★ kill host cells slowly</td>
<td>★ kill host cells rapidly by producing toxins or enzymes</td>
</tr>
<tr>
<td>★ penetrate directly or via natural openings</td>
<td>★ penetrate through wounds or natural openings</td>
</tr>
</tbody>
</table>

**Common Diseases Caused by Biotrophs:**
- nematode diseases
- phytoplasma diseases
- virus diseases
- downy mildews
- powdery mildews
- rusts

**Common Diseases Caused by Necrotrophs:**
- anthracnoses
- cankers
- fruit rots
- leaf spots and blights
- root rots
- vascular wilts
E. Disease cycle (succession of events that occur during the development of disease)

- When the interaction between plant and a pathogen result in disease, the interactions are called disease cycle.
- It is important to be able to identify stages in disease cycle because they will suggest ways to prevent and manage disease.
- **Inoculum**: capable of causing infection when transferred to a favorable location i.e. spores.
- **Primary inculum**: pathogen or its parts that initiates disease in the field.
- **Dispersal**: spread of infectious material (inoculum) from diseased to healthy plants. i.e. wind, rain splash, sticky polysaccharides, spores, insects, seed (pressurized).
- **Infection court**: Part of the plant that can be invaded. i.e. wounds, soft tissues such as flowers or young leaves, stoma. **Indirect versus direct penetration**.
- **Infection**: process in which an organism enters, invades, or penetrates and establishes a parasitic relationship with a host plant.
- **Incubation period**: the time between penetration of a host by a pathogen and the first appearance of disease symptoms.
- **Colonization**: establishment and ramification of a pathogen within a host plant.
- **Secondary inoculum**: inoculum produced by infections that took place during the same growing season.
- **Survival**: Once growing season is over, pathogens must be able to survive either in plant tissues in perennial plants, or specialized structures such as special spores, biofilms, eggs, seed colonization, etc.