Introduction to Plant Disease Epidemiology

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Grading:

Assignments (100%).

Readings from:

(1) Chapters in Introduction to Plant Disease Epidemiology by C. L. Campbell & L. V. Madden (1990)

(2) Chapters in Introduction to Plant Disease Identification and Management. G.B. Lucas, C.L. Campbell, and L.T. Lucas (1985)

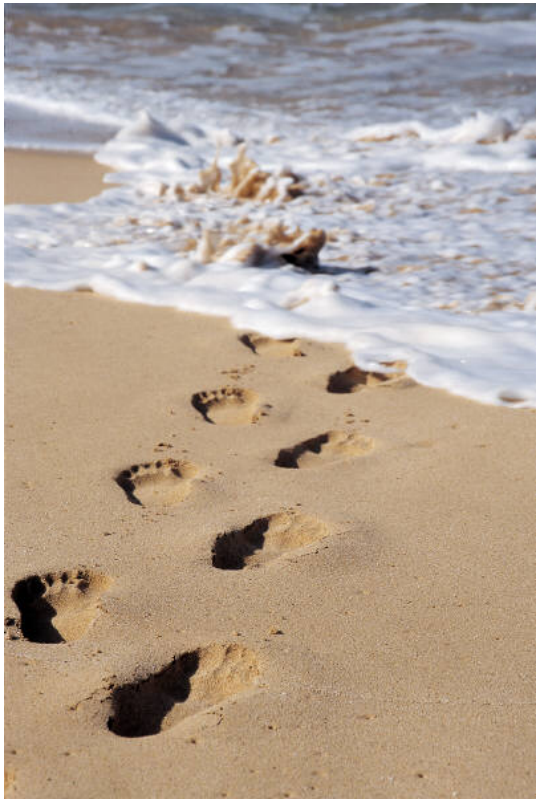
(3) Chapters in Plant Pathology. George N. Agrios (1978)

(4) Chapters in Experimental Techniques in Plant Disease Epidemiology. Jurgen Kranz and Joseph Rotem (1988)

(5) Chapters in Epidemiology: An Introduction. Kenneth J. Rothman (2012)

Lecture 1

History of Epidemiology



Historical Epidemics

Year(S)	Epidemic and Consequence	Reference
857	First recorded epidemics of ergotism. Thousands dired in the Rhine Valley.	Carefoot and Sprott, 1967
1039	Ergotism in France: monks of the Order of St. Anthony relieved many symptoms.	Carefoot and Sprott, 1967
1722	Ergotism at Astrakhan: aided in defeat of Peter the Great of Russia	Carefoot and Sprott, 1967
1845-1846	Late blight of potato: Irish potato famine: 1 million Irishmen died of starvation and related maladies, another 2 million egigrated.	Bourke, 1964; Carefoot and Sprott, 1967; WoodhamSmith, 1962
1845-1860	Powdery mildew of grape in England and France: finacial loss and importation of Phylloxera aphid from North America	Large, 1940; Carefoot and Sprott, 1967
1882-1885	Downy mildew of grape in France: financial loss and discovery of Bordeaux mixture	Large, 1940; Carefoot and Sprott, 1967
1870-1880	Coffe rust in Ceylon: financial ruin for planters; English people became primarily tea drinkers	Large, 1940; Carefoot and Sprott, 1967
1904-present	Chestnut blight in the United States: destruction of American chestnut as a forest tree species in eastern United States; financial loss	Hepting, 1974
1913	Leaf spot on banana cultivar Gros Michaels in the Sigatoka Valley in Fiji: financial loss	Carefoot and Sprott, 1967
1915-23; 1930-35	Panama disease of bananas in Costa Rica, Panama, Columbia, and Guatemala: financial loss	Carefoot and Sprott, 1967
1916-1917	Late blight of potato in Germany: food shortages in civilian population; contributing factor to demoralization of German troops in World War I	Carefoot and Sprott, 1967

History of Plant Epidemiology Cont.

Year(S)	Epidemic and Consequence	Reference
1930-	Dutch elm disease in USA: loss of American elm as share tree species in many areas; loss of property value.	Carefoot and Sprott, 1967
1942-1943	Leaf blight of rice in Bengal: great Bengal famine-nearly 2 million people died from starvation.	Carefoot and Sprott, 1967
1951	Ergotism at Pont-St.-Esprit, France: 4 deaths, 32 cases of insanity, numberous cases of hallucinations.	Fuller, 1968
1970	Southern maize leaf blight in USA: 15% of US maize crop lost.	Horsfall, 1972
1977-1978	Ergotism in Ethiopia: hallucinations, human suffering, and death	Demeke et al., 1979
1979-1980	Blue mold of tobacco in eastern United States and Canada: financial loss	Lucas, 1980

History (ancient to modern times):

- Hippocrates (~400 BC)

  First use of “epidemic”, widespread disease (human diseases)

- Theophrastus (~340 BC)

  Plant diseases in fields; Environment influnces

- Pliny (~50 AD)

  Plant diseases; soil; climate

- Duhamel de Monceau (1728 AD)

  Rhizoctonia sp. infecting asffron crocus

  Disease progress curves

  Comparison of plant and animal epidemics

Late 19th century and forward:

- Kuhn (1858)

  1st textbook of plant pathology

- Ward (1901)

  book “Diseases in Plants” emphasized ecology (populations)

- Jones (1913)

  role of the environment

- Gaumann (1946)

  Principles of Plant Infection

  -Disease spread

  -Conditions leading to an epidemic

  -Infection chain

  -Compare with medicine (disease of human)

  -Theory (initial, in words)

- Large (1952, and others)
  - -Disease progress curves
  - -Crop losses
  - -Disease assessment (measurement)
- Horsfall & Dimond (1960)

  book “Plant Pathology, Volume 3”
  - - populations
  - - inoculum density
  - - spore dispersal
  - - analysis (mathematics)
  - - forecasting, prediction
  - - traditional definition ----→modern definition
- Gregory (1963, 1973)

  “The Microbiology of the Atmosphere”
  - - spore dispersal, disease spread

- Vanderplank (1963)

  “Plant Disease: Epidemics and Control”

  - Populations
  - Rates (dynamic processes)
  - Analysis, mathematics
  - Models, theory
  - Link epidemiology and control
  - Established the science of plant disease epidemiology

- Other pioneers:

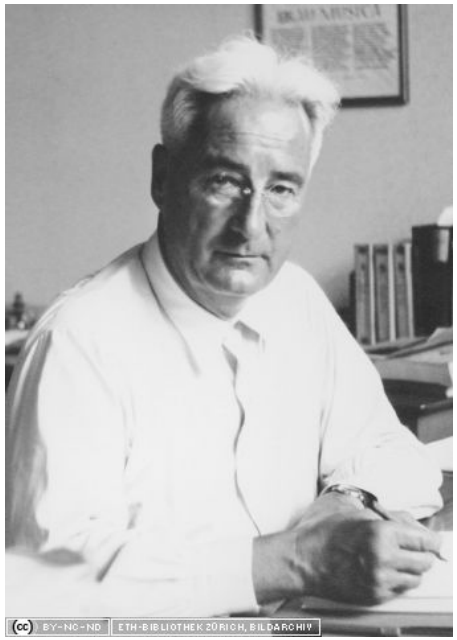
  Zadoks (1960-1995), The Netherland

  Kranz (1968-1995), Germany

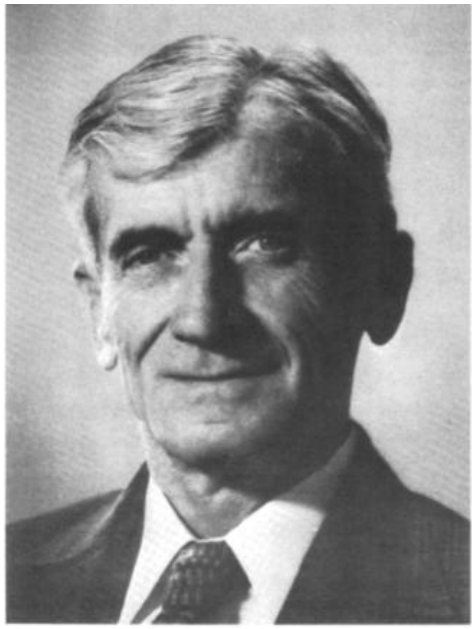
  Waggoner (1960-mid 1980s), USA

  Larry Madden (??), USA

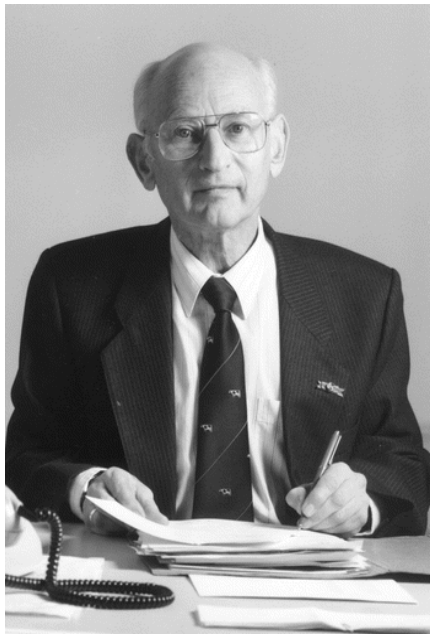
历史



Gäumann, E



Vanderplank, J E



Zadoks, JC

Laurence V Madden

Lee campbell-C

曾士迈

刘汉文

李振岐

Concept and impression

Lecture 2

What is plant disease epidemiology?

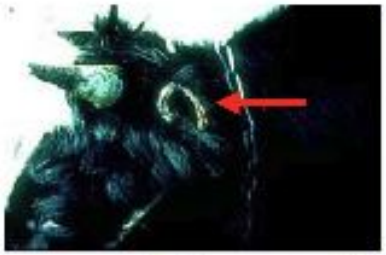
The study of the survival and spread of pathogens and the development of a disease in a population of plants over time is called epidemiology.

---------Introduction to Plant Dieases, Lucas GB, Campell CL, and Lucas LT. 1985

Ergot of Rye

Ergot of Rye

- Ergot is a disease of Rye. The **Ergot** is the dark purplish **sclerotium** of the fungus that replaces the grain.



- Cow with gangrenous ergotism.

Loss of toes in foot due to gangrene.

- Gangrene of finger tips.

Potato Late Blight, The Netherland, 2008

向日葵黑茎病，新疆伊犁，2010

向日葵黑茎病, 2011 (Soilborne Lab., NWAF)

荷兰榆树病, 美国, 1995

Verticillium wilt of sunflower, Ningxia, 2010

Verticillium Wilt of strawberry

Dieback, Australia, 2012

紫荆黄萎病, 2012 (Soilborne Lab., NWSUAF)

Chinese redbud Wilt

Chinese redbud Wilt, 2012 (Soilborne Lab., NWAF)

乌拉尔甘草枯萎病, 2012

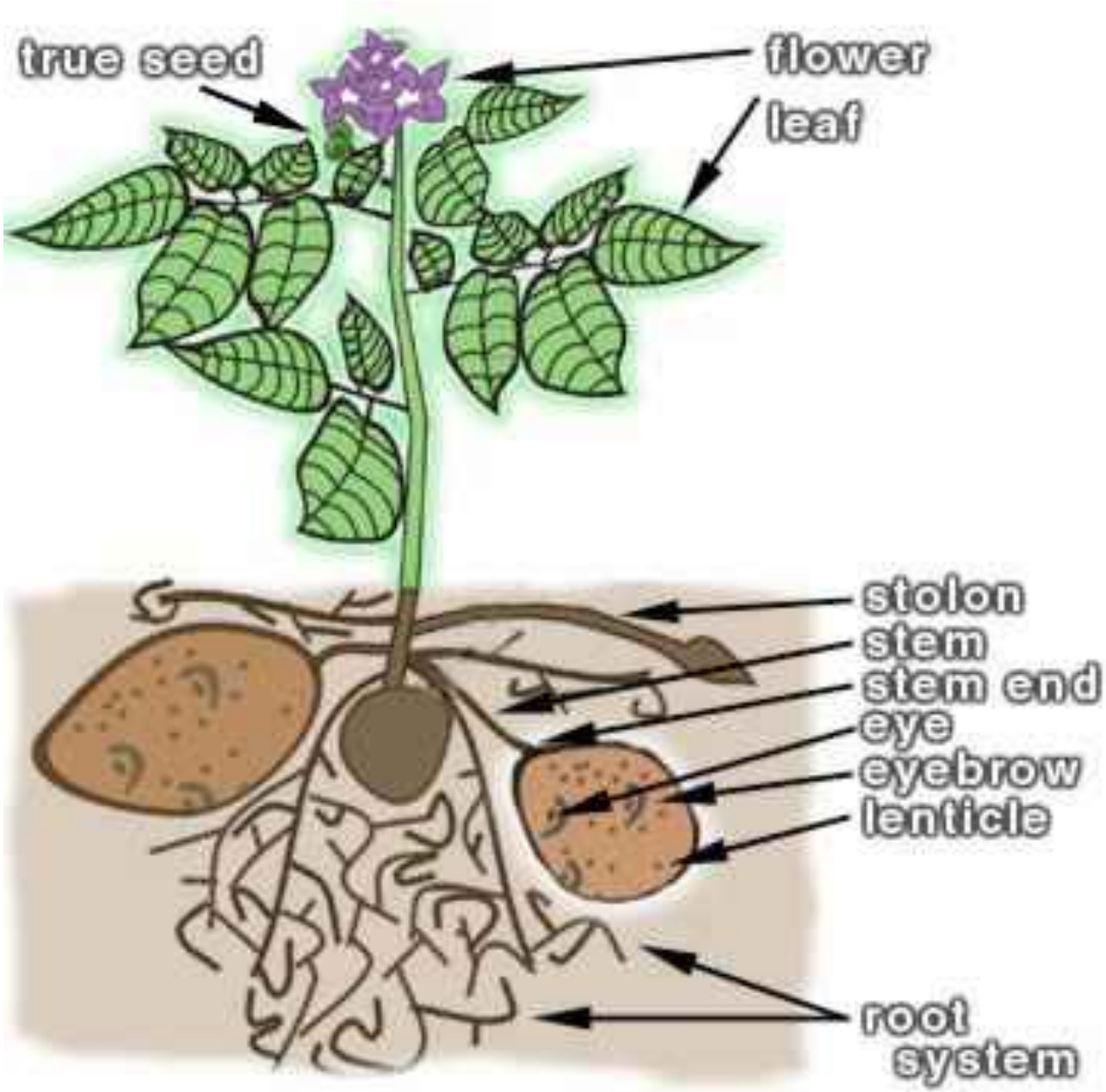
Fusarium Wilt and Root Rot of liquorice

(Soilborne Lab., NWAF)

中国马铃薯

Potato in Europe

Potato Plant



Irish Potato Famine

During the Irish big famine time, a man who prpared to immigrete was watching the American New York's playbill before departure.

Irish Potato Famine

Tom Sullivan of County Kerry comtemplates the extent of the blight.

Pictorial Times - 1846

Turbulent opening of the store in Cork selling Peel's Indian Corn.

Illustrated London News - 1846

By October 1845, news of the blight had reached London. British Prime Minister, Sir Robert Peel, quickly established a Scientific Commission to examine the problem. After briefly studying the situation, the Commission issued a gloomy report that over half of Ireland's potato crop might perish due to 'wet rot.'

The corn meal itself also caused problems. Normally, the Irish ate enormous meals of boiled potatoes three times a day. A working man might eat up to fourteen pounds each day. They found Indian corn to be an unsatisfying substitute. Peasants nicknamed the bright yellow substance 'Peel's brimstone.' It was difficult to cook, hard to digest and caused diarrhea. Most of all, it lacked the belly-filling bulk of the potato. It also lacked Vitamin C and resulted in scurvy, a condition previously unknown in Ireland due to the normal consumption of potatoes rich in Vitamin C.

Irish Potato Famine

Irish Potato Famine

A starving boy and girl in Cork hoping to find a potato.

Illustrated London News - 1847

Holding her dead child, a mother begs for enough money to get a coffin.

Illustrated London News - 1847

Irish Potato Famine

The ruined Village of Tullig in County Clare.

Illustrated London News - 1850

Potato Famine

ATTACK ON A POTATOE STORE.

Late blight of potato on leaf, stem, tuber

Take all of wheat

Take All Disease of Wheat in Dali County in May,1998

Gaeumannomyces graminis f. sp.*tritici*

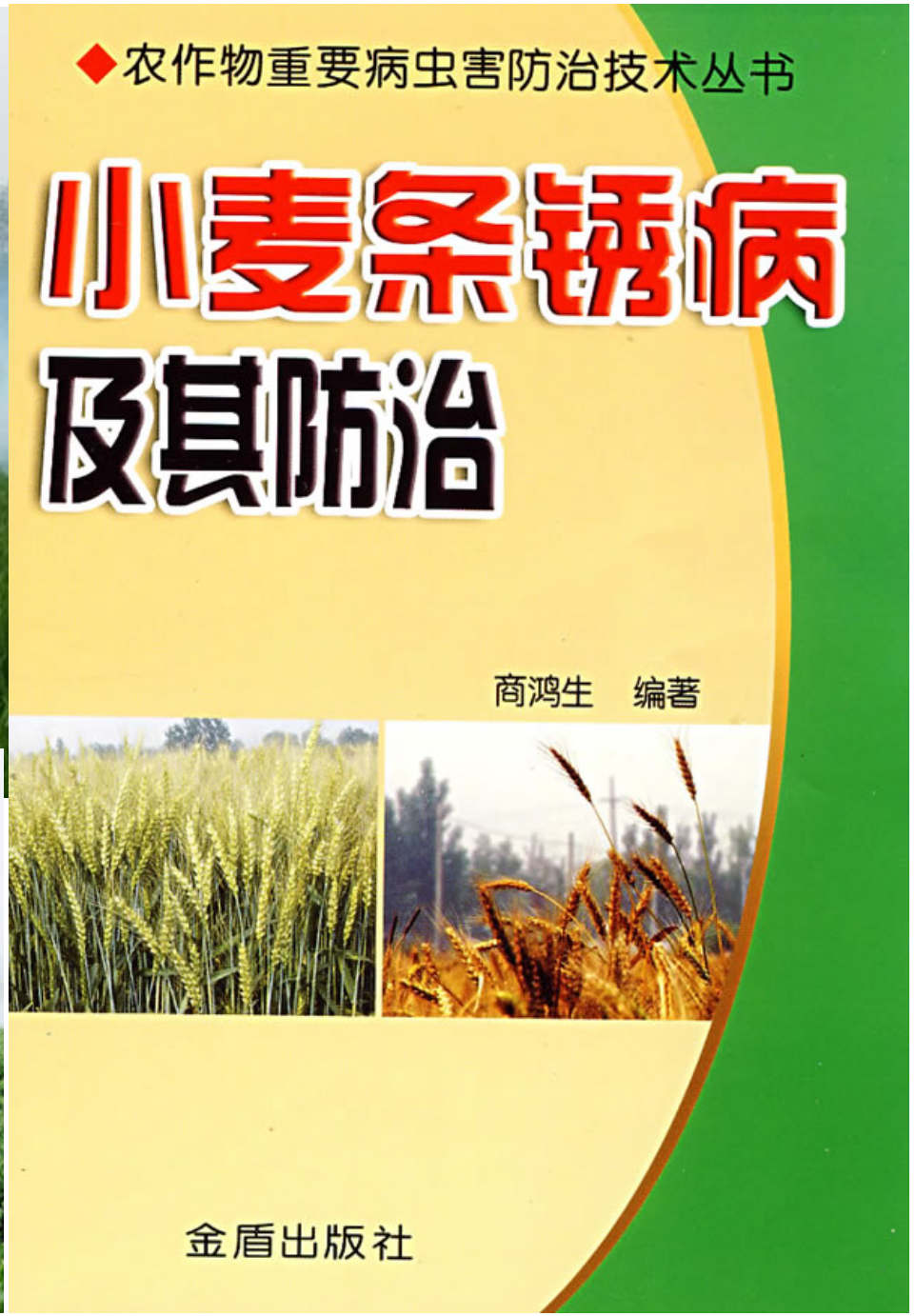
Take all patch outbreaks.

Patches are circular because the fungus grows outward in a radial fashion from the initial site of establishment. Patches range in diameter from 8 to 24 inches and usually occur in clusters.

Wheat Stripe Rust

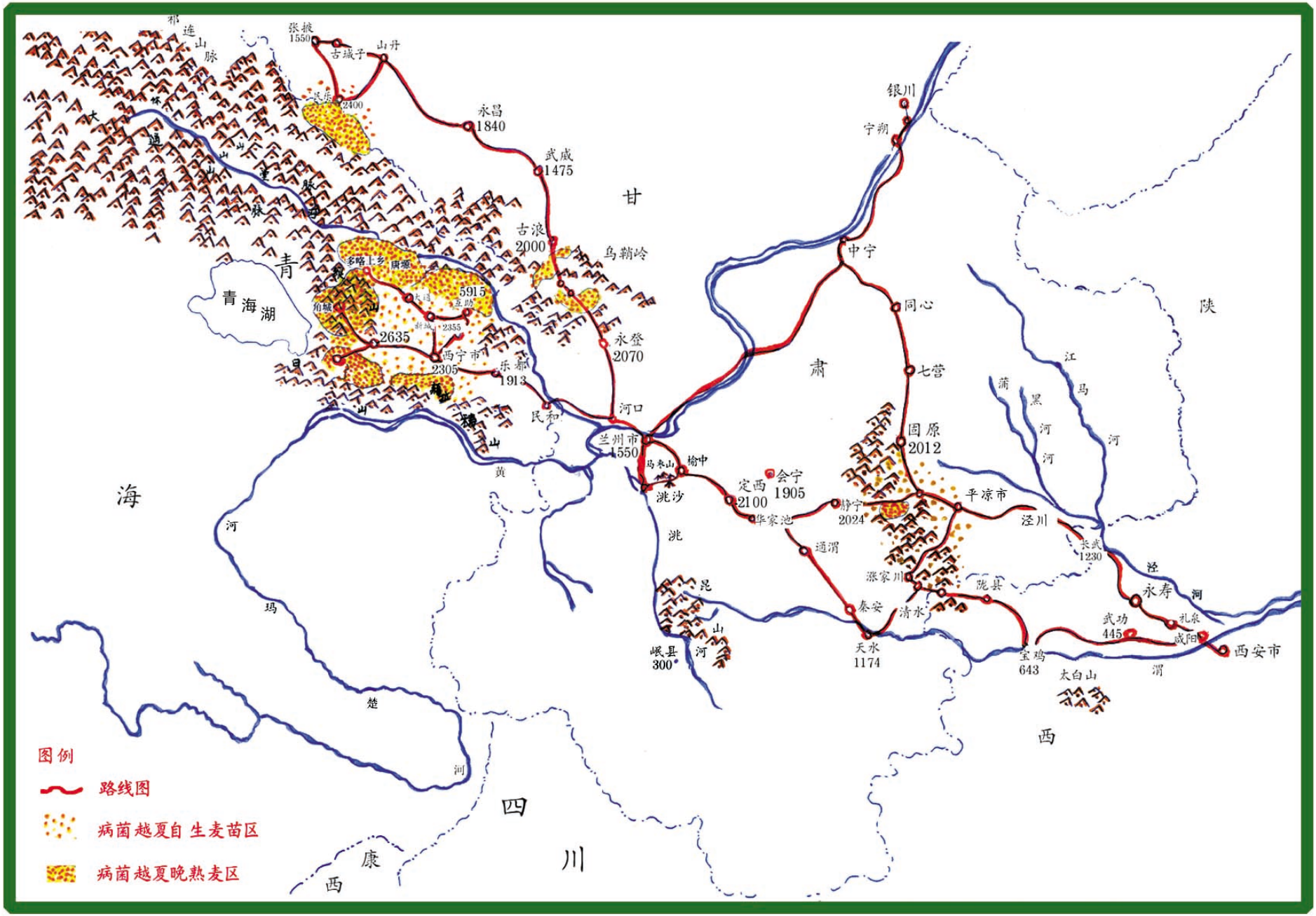
Wheat stripe rust.

Wheat stripe rust.

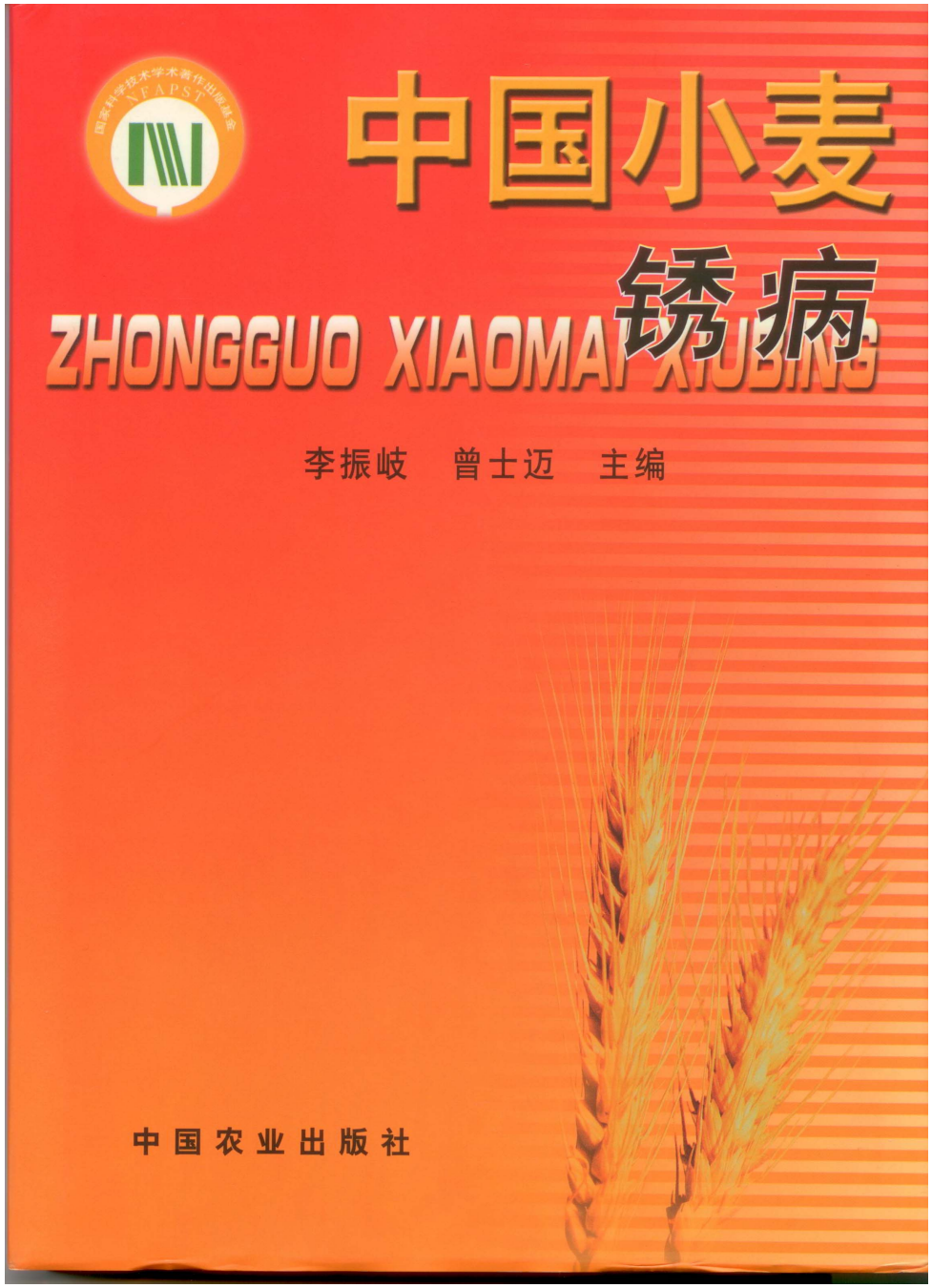


Wheat stripe rust transmission routes.

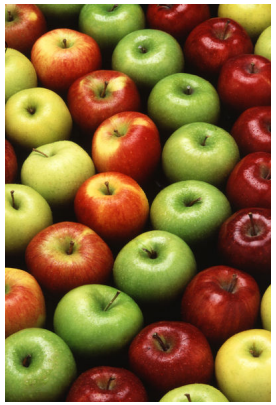
1951-1953年陕、甘、青小麦条锈病菌越夏情况调查路线及越夏场所分布图



Monograph



Apple scab.



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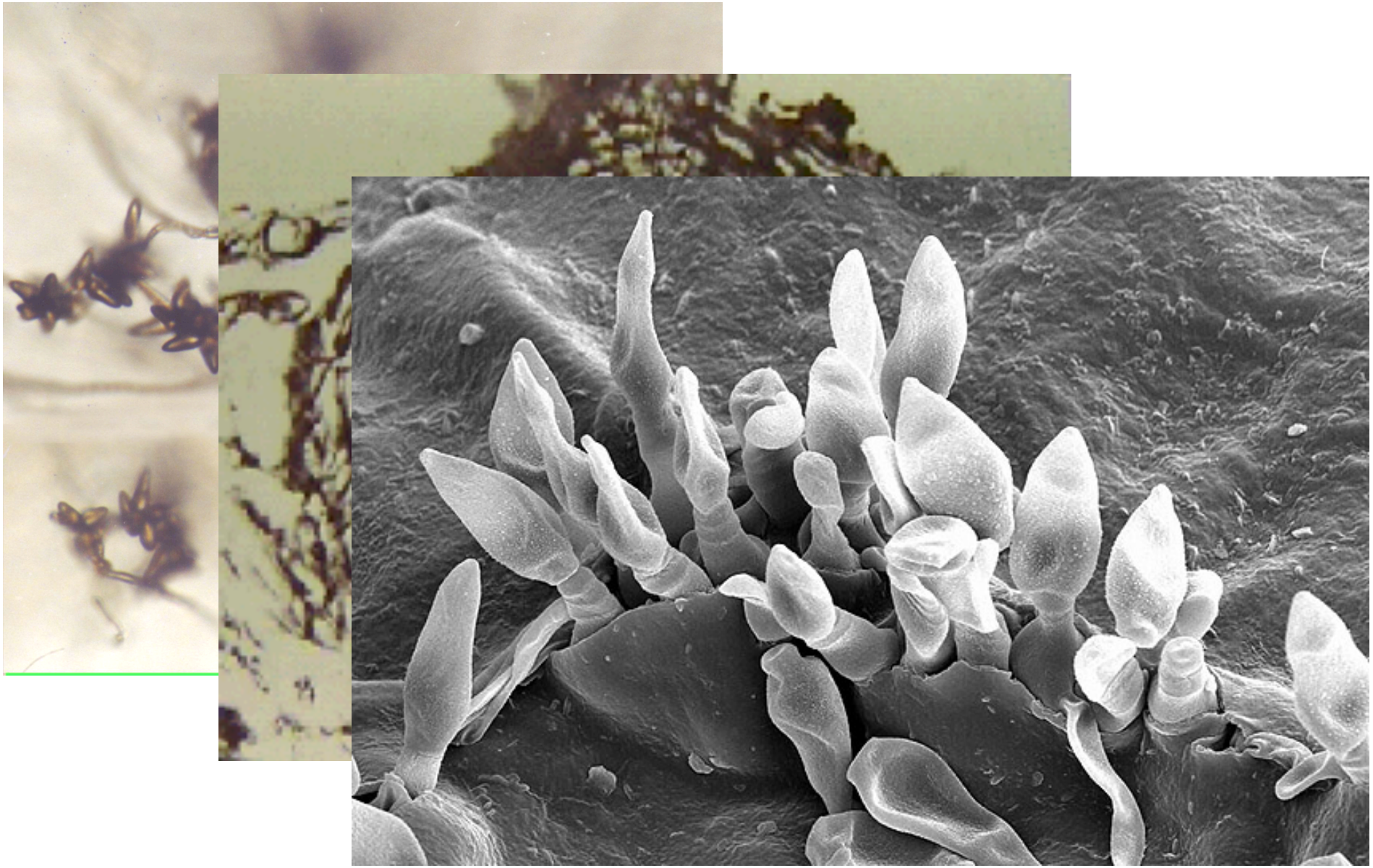

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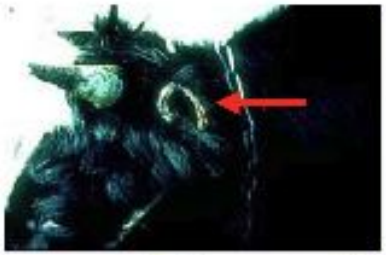

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Lecture 3

Outline of Epidemiology

Lecture 2: Structure of Plant Disease Epidemiology

What is epidemiology?

How it relates to other sciences and disciplines.

Types of research performed by epidemiologists.

Questions addressed by epidemiologists.

Usefulness of epidemiology for control/management.

Concept

"Chemical industry and plant breeders have forged fine technical weapons, but only epidemiology sets the strategy." Vanderplank (**1963**)

More specific objectives:

To gain an understanding of how plant disease epidemics occur in nature and how they can be monitored and analyzed.

To learn how plant diseases cause crop losses, how these losses are quantified, and how losses are predicted.

To learn how epidemiology is used to set the strategy of plant disease control.

To learn how to use some statistical procedures for quantifying and comparing and predicting epidemics.

Terminology

Epidemic: "*Change in disease intensity in a host population over time and space.*"

Change: often *increase* **--a dynamic process**

Disease: dealing with **diseases,** not just the pathogen (or plant/crop)

Host: Organism infected (or potentially infected) by another organism

Population: a **population phenomenon**

Time and space: two **physical dimensions** of interest.

Epidemiology *"Science of disease in populations"*
Vanderplank (1963)

System

Community

Population

Individual

Organ

Tissue

Cellular

Molecular

Concept

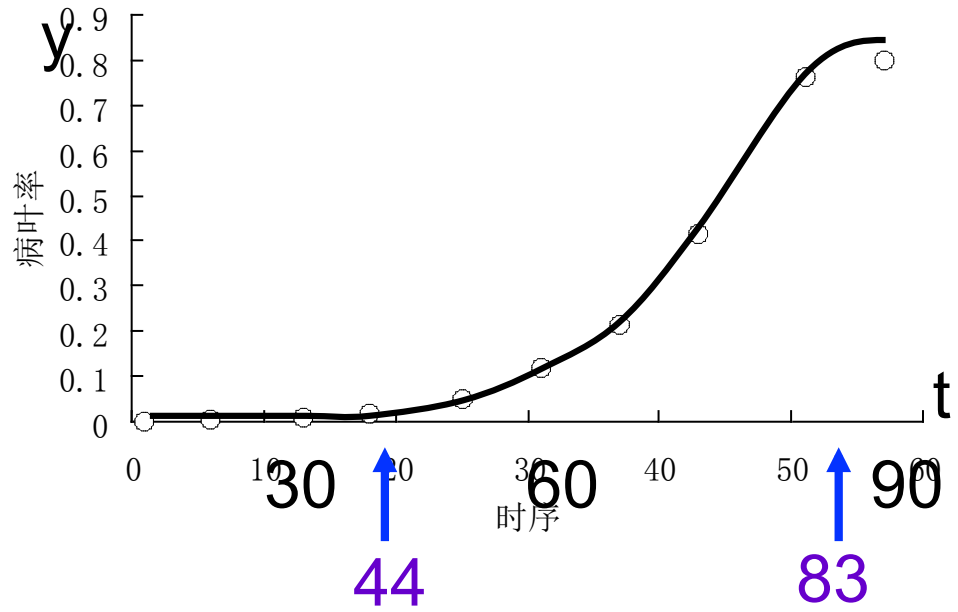
Epidemic does not mean widespread and/or high level of disease!
We use ***pandemic*** for widespread, high disease level ("major epidemic")

Consider an **epidemic** of potato late blight, caused by Phytophthora infestans...

LATE BLIGHT OF POTATO:

A large field with 4 million plants ($4x10^6$)
1 lesion/plant: 0.1% severity (that is, y = 0.001 or 1/1000 of the leaf surface covered by lesions) (Practical limit of detection)

Disease progress curve



t=44 y = 0.001 (or 0.1%)
(or 1 lesion/plant)
t=83 y = 0.999 (or ~100%)
t=0 1 lesion/field
(or y = 0.001/[$4x10^6$]
= $2.5x10^{-10}$)
t=44 1 lesion/plant
(or $4x10^6$ lesions/field,
or y = 0.001)
(Practical limit of detection)

Lension/time/severity

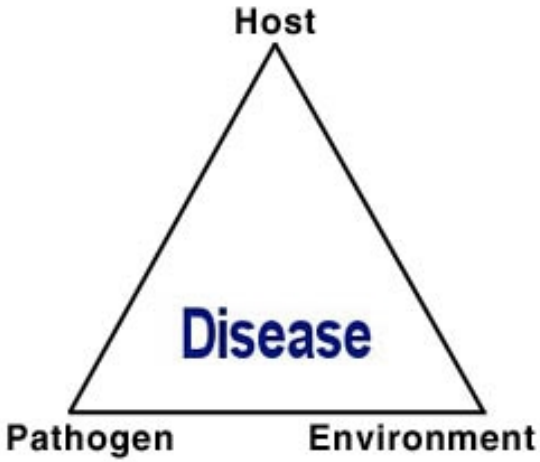
t (day)	Severity	Lesions
0	0.00000000025	1
10	0.0000000080	32
20	0.00000026	1022
30	0.000012	32695
40	0.00026	1045221
50	0.0083	33154000
60	0.21	
70	0.895	
80	0.996	

Study of epidemics.

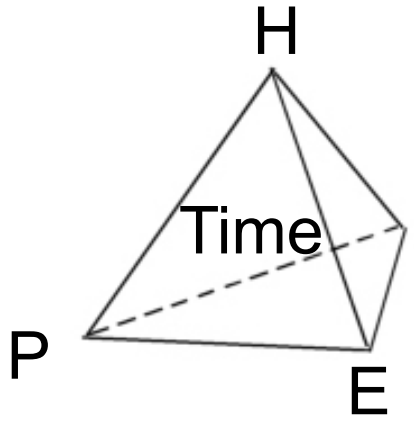
- *Science of disease in populations.*
- *Ecology of disease.*
- *Study of the spread of diseases, in space and time, with the objective to trace factors that are responsible for, or contribute to, epidemic occurrence.*
- *The science of populations of pathogens in populations of host plants, and the diseases resulting there from under the influence of the environment and human interferences.*

Triangle/square

Involves the disease triangle, but at the population level.



Some efforts have been made to extend the disease triangle to encompass the dimensions of time and space (and other factors). This become awkward since we are limited to pseudo-3-dimensions.



Reading assignment #1:

1. Factors data aquired, e.g. Spore number, Rainfall, Temperature, Leaf Wetness Duration, RH, Soil Temperature, etc.

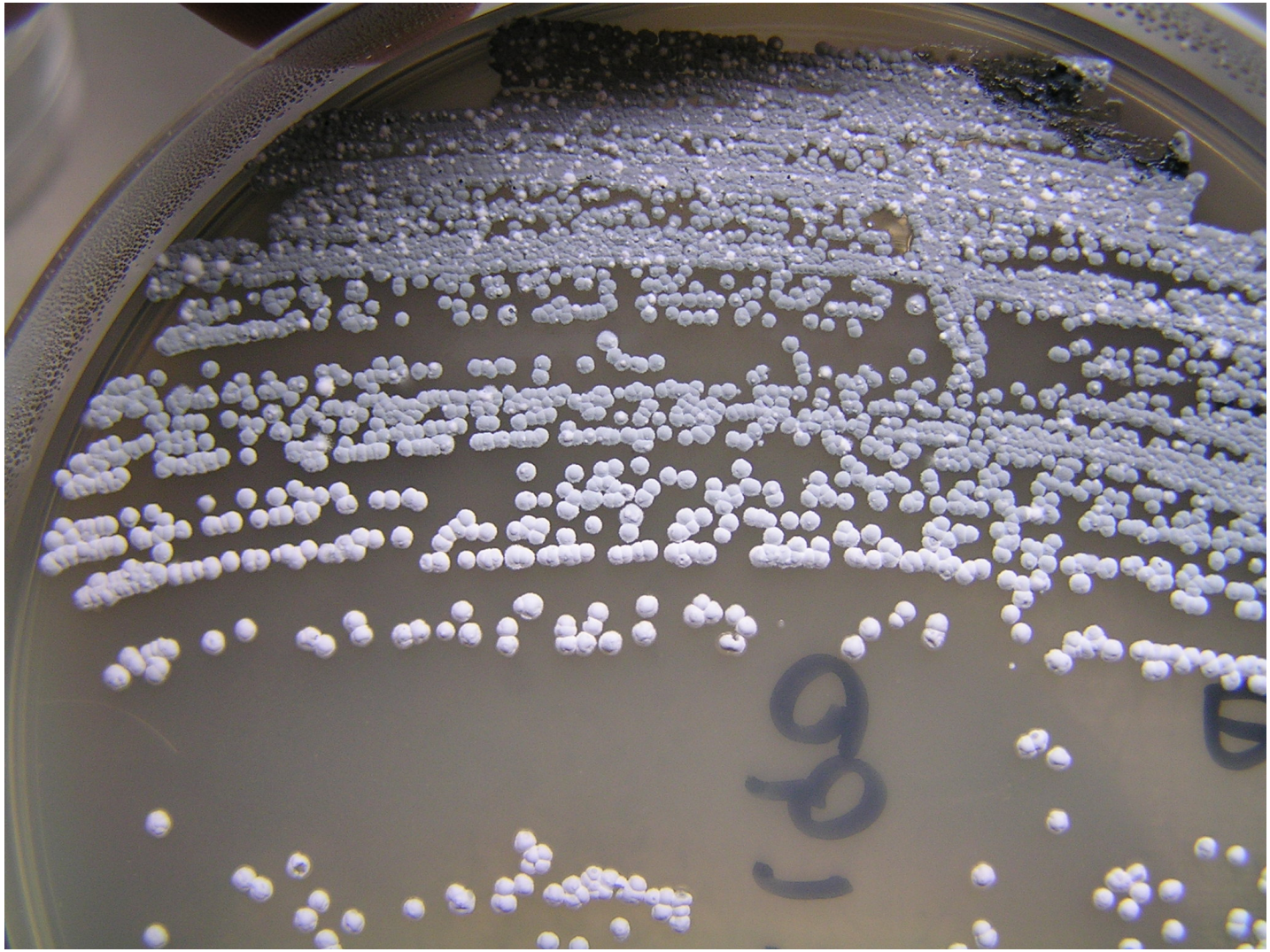
2. Epidemic factor analysis. Methods, Analysis Software (SAS, SPSS, Matlab, etc.)

3.

Lecture 4

Basic Measurement Methods of Epidemiology

Host, Pathogen, Disease Measurement



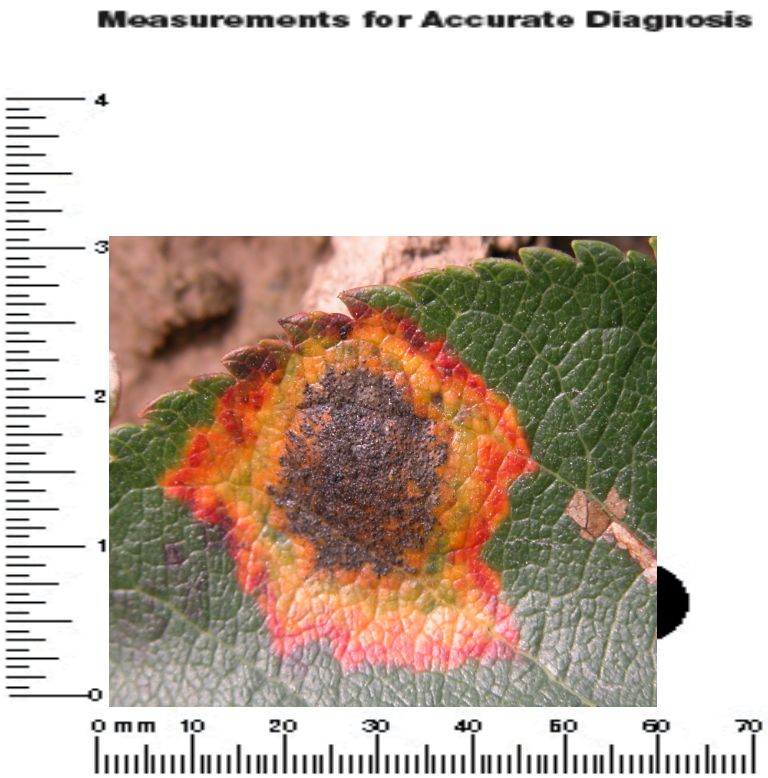
Monitoring epidemics

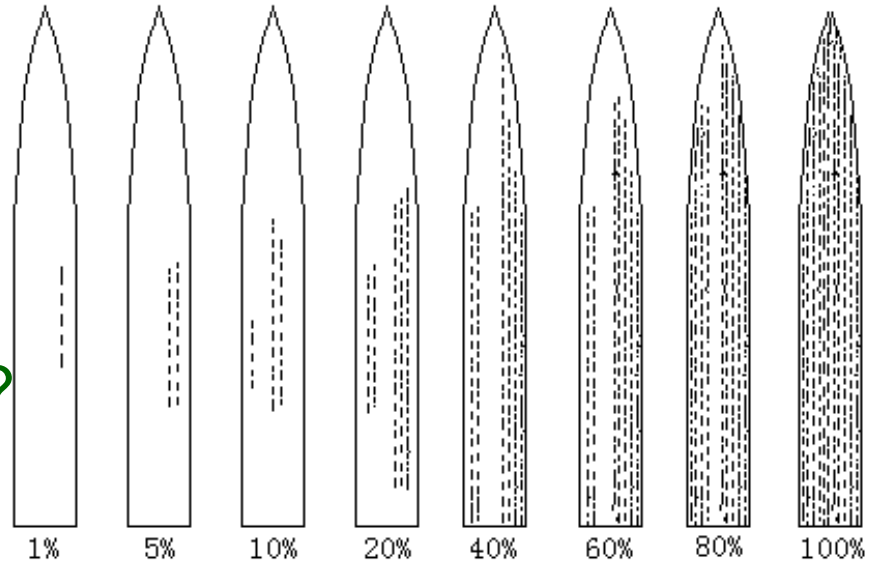
Host measurement

Disease measurement

Severity-incidence

Pathogen measurement?






M1 M2 M3 M4 M5 S1 S2 S3 S4 S5

Lecture 5

Epidemiology Glossary

1. Confidence Interval (CI):

Usually calculated as ″95% confidence intervals″, indicating that there is a 95% probability that the effect of treatment in the whole population lies within the stated range. The CI is affected by sample size and by variability among subjects.

2. Incidence

The number of new cases of disease within a given time period.

3. AUDPC (abbr. for Area Under Disease Progress Curve)

A measure of the total amount of disease over a period of time, determined from graphs of disease vs. time, which can be used to compare epidemics quantitatively.

4. avirulence (*avr*) gene

Gene in a pathogen that usually causes a hypersensitive reaction, is associated with active plant defense reactions in a resistant plant, and causes disease in a susceptible plant.

5. biotype

A subdivision of a species, subspecies, or race based on some identifiable physiological trait such as a specific virulence pattern.

6. canopy

the expanded leafy top of a plant or plants

7. cfu (abbr. for colony forming unit)

the number of colonies formed per unit of volume or weight of a cell or spore suspension

8. colonization

establishment and ramification of a pathogen within a host plant

9. cross-protection

the process whereby a normally susceptible host is infected with a less virulent pathogen (usually a virus) and thereby becomes resistant to infection by a second, usually related, more virulent pathogen

10. degree-day

the departure of the average daily temperature from a defined base (e.g. the minimum recognized temperature for the growth of a plant species). The number of degree-days may be totaled to assess the accumulated warmth of a particular year's growing season.

11. differential host (syn. differential cultivar)

a plant host that on the basis of disease symptoms serves to distinguish between various strains or races of a given plant pathogen

12. dilution streaking

repeated streaking of bacteria on the surface of a nutrient medium with a sterile metal loop to allow pure colonies to grow

13. disease cycle

succession of all of events and interactions among the host, parasite and environment that occur in a disease, from initial infection of the plant by a causal agent, through pathogenesis, to over-seasoning, until another infection occurs

14. disease incidence
number of plants affected by a disease within a population

15. disease progress curve
graph of some measure of disease (i.e. severity) over time

16. disease pyramid
a memory aid similar to the disease triangle but including, in addition, the factor of time in the development of a disease

17. disease triangle
a memory aid that diagrams the three important components necessary for disease: susceptible plant, virulent pathogen and favorable environment

18. dispersal (syn. dissemination)
spread of infectious material (inoculum) from diseased to healthy plants

19. economic threshold
the pathogen density at or above which the value of crop losses (in the absence of management efforts) would exceed the cost of management practices

20. epidemiology (adj. epidemiologic)
the study of factors influencing the initiation, development, and spread of infectious disease; the study of disease in populations of plants

21. f. sp. (abbr. for *forma specialis*)
a taxonomic group within a pathogenic species defined in terms of host range, i.e. members of different *formae speciales* infect different groups of plants

22. general resistance (syn. horizontal resistance, race non -specific resistance)
resistance that is effective against all biotypes of the pathogen

23. gene-for-gene hypothesis
the hypothesis that corresponding genes for resistance and virulence exist in the host and pathogen, respectively

24. in planta
in a plant

25. in situ
in its original place or environment

26. in vitro
in glass, on artificial media, or in an artificial environment; outside the host

27. in vivo
within a living organism

28. incubation period
the time between penetration of a host by a pathogen and the first appearance of disease symptoms; the time during which microorganisms inoculated onto a medium are allowed to grow

29. infection period
the time required for infection to occur under conducive environmental conditions, usually hours of leaf wetness and temperature

30. initial inoculum (syn. primary inoculum)
inoculum, usually from an overwintering source, that initiates disease in the field, as opposed to inoculum that spreads disease during the season

31 inoculum (pl. inocula)
pathogen or its parts, capable of causing infection when transferred to a favorable location

32. inoculum density
a measure of the number of propagules of a pathogenic organism per unit area or volume

33. latent period
the time between infection and the production of new inoculum; the time after a vector has acquired a pathogen and before it can be transmitted

34. monocyclic

having one disease or life cycle per growing season

35. polycyclic

having several to many disease cycles in a growing season (see monocyclic)

36. overwinter

to survive or persist through the winter period

37. pandemic

a widespread and destructive outbreak of disease simultaneously in several countries

38. rotation

growth of different kinds of crops in succession in the same field

39. sanitation

destruction or removal of infected and infested plants or plant parts; decontamination of tools, equipment, containers, work space, hands, etc.