Week5/Lesson5

Commonly used Rates/ratios and Spatial Diffusion of Disease

- ✓ More rates and ratios
- ✓ "Show and tell" : How to calculate life tables
- ✓ The Crucial Role of Diffusion
- ✓ Types of diffusion
- ✓ Modeling diffusion
- ✓ Barriers vs. networks

More Ratios:

Sex Ratio - M/F x 100

Maternal Mortality Ratio (D_m per 100,000 births): **Defined as** the death of a woman while pregnant or within 42 days of termination of pregnancy, irrespective of the duration and site of the pregnancy, (WHO)

Two types of Rates:

- **Crude (denominator = total pop.)**
- **Age-specific (both numerator and denominator relate to a specific age)**

Crude Death Rate:

$$CDR = \frac{D}{P} \times 1000$$

Where:

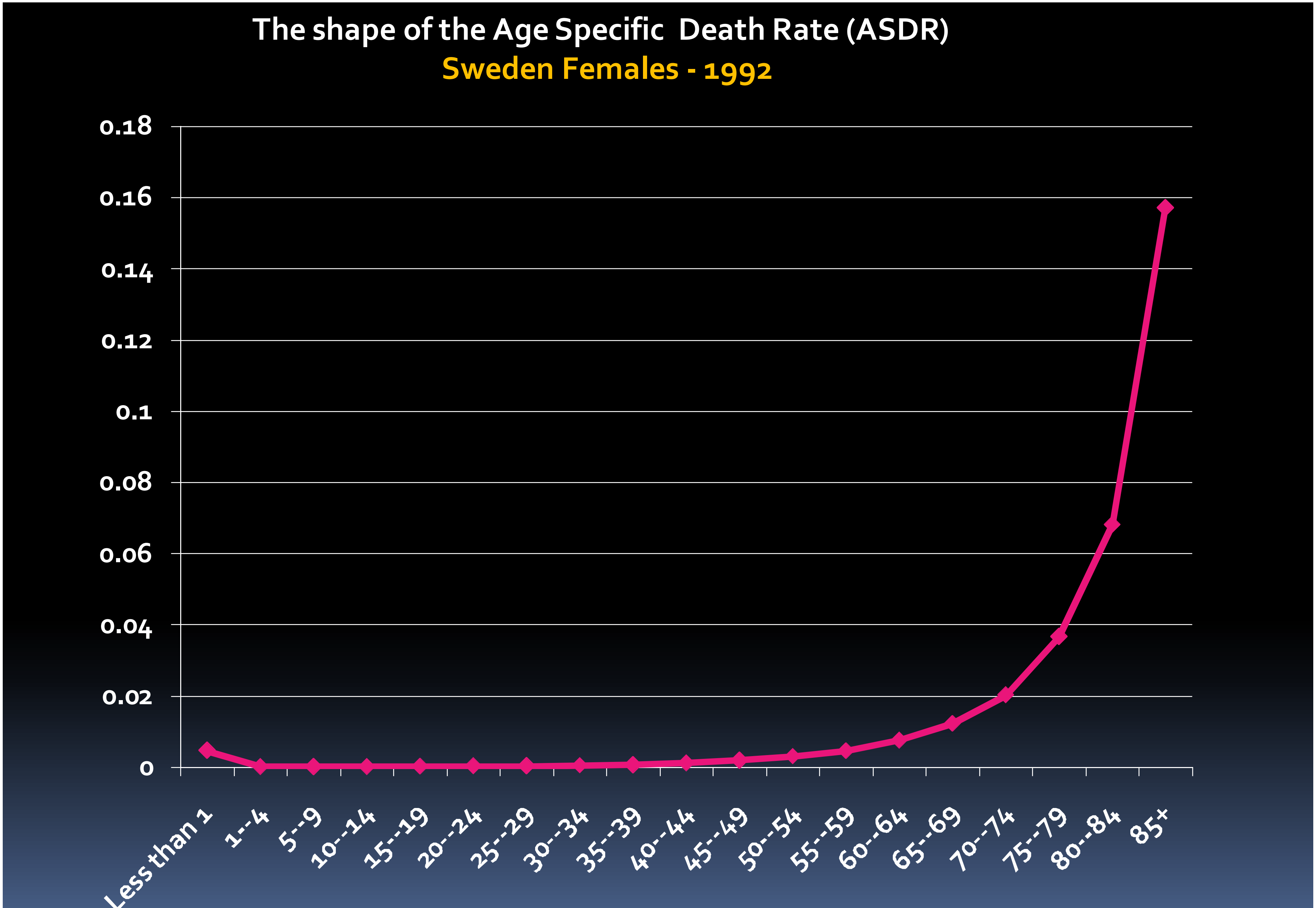
D : Number of deaths in one year

P: The total mid-year population

Age-Specific Rates

- The probability of dying is closely linked to <u>AGE</u>
- **ASDR for a grouped data with a starting age *x* and an age interval *n* (*n* usually equals 5)**

$$_{n}M_{x} = \frac{_{n}D_{x}}{_{n}P_{x}}$$



Note: the ASDR below age 1 is higher than the rate in the 1-4 age group in all countries

The ASDR **below age 1** is also known as the infant mortality rate **(IMR)** .

A. **Infant mortality** ($_1q_0$): the probability of dying between birth and the first birthday = $D_{0-364}/B \times 1000$

Due to its uniqueness, the ASDRB below age 1 **(IMR)** is further divided in two as:

B. **Neonatal mortality** (NN): the probability of dying within the first month of life. $D_{0-28}/B \times 1000$

C. **Post-neonatal mortality** (PNN): the difference between infant and neonatal mortality $D_{29-364}/B \times 1000$

A = B + C

Additional childhood mortality rates include:

D. **Child mortality** ($_4q_1$): the probability of dying between exact age one and five. $D_{1-4}/B \times 1000$

E. **Under-five mortality** ($_5q_0$): the probability of dying between birth and the fifth birthday $D_{0-5}/B \times 1000$

E = A + D

Infant Mortality Rates 2008

1. Singapore 2.0
2. Hong Kong 2.5
3. Japan 2.8
4. Sweden 3.1
5. Norway 3.2
6. Finland 3.3

27. Cuba   5.8

29 . USA   6.9

. . . . .

Afganistan 157

Sieraleone 158

Angola   184

The main application of ASDR ($_n\mathrm{M}_x$) is in calculation of life expectancies at birth and at higher ages (at national, regional, and sub-population levels).

Life Expectancy at Birth (2007).

Canada 80.3

Sweden, Switzerland 80.6

Japan 81.4

USA 78.0

Mozambique 40.9 (AIDS effect)

Angola 37.6 (AIDS effect)

South Africa 42.5 (AIDS effect)

Maternal Mortality Ratios:

"Maternal mortality and morbidity in Ethiopia are among the highest in the world (an estimated **720 per 100,000** live births) and stems from a range of socioeconomic, political, and demographic factors."

http://www.popcouncil.org/projects/283_VerbalAutopsyEthiopia.asp

2008

Afghanistan 1400

Chad, Somalia 1200

USA 8

Italy, Iceland, Denmark, Austria 5

http://www.childinfo.org/maternal_mortality_countrydata.php

Diffusion

"The dynamics by which a phenomenon originally located at one point becomes transferred to another is a question which is as difficult to answer as it is easy to pose" (Cliff *et al*, 1981 p. 191).

"There are only two ways in which anything – whether it be an idea, a type of mosquito, a food crop, a sophisticated technology for hospital care, or an infectious agent of disease – can come to be found in a particular location. Either it developed there independently or it somehow moved there from another place" Text

Diffusion:

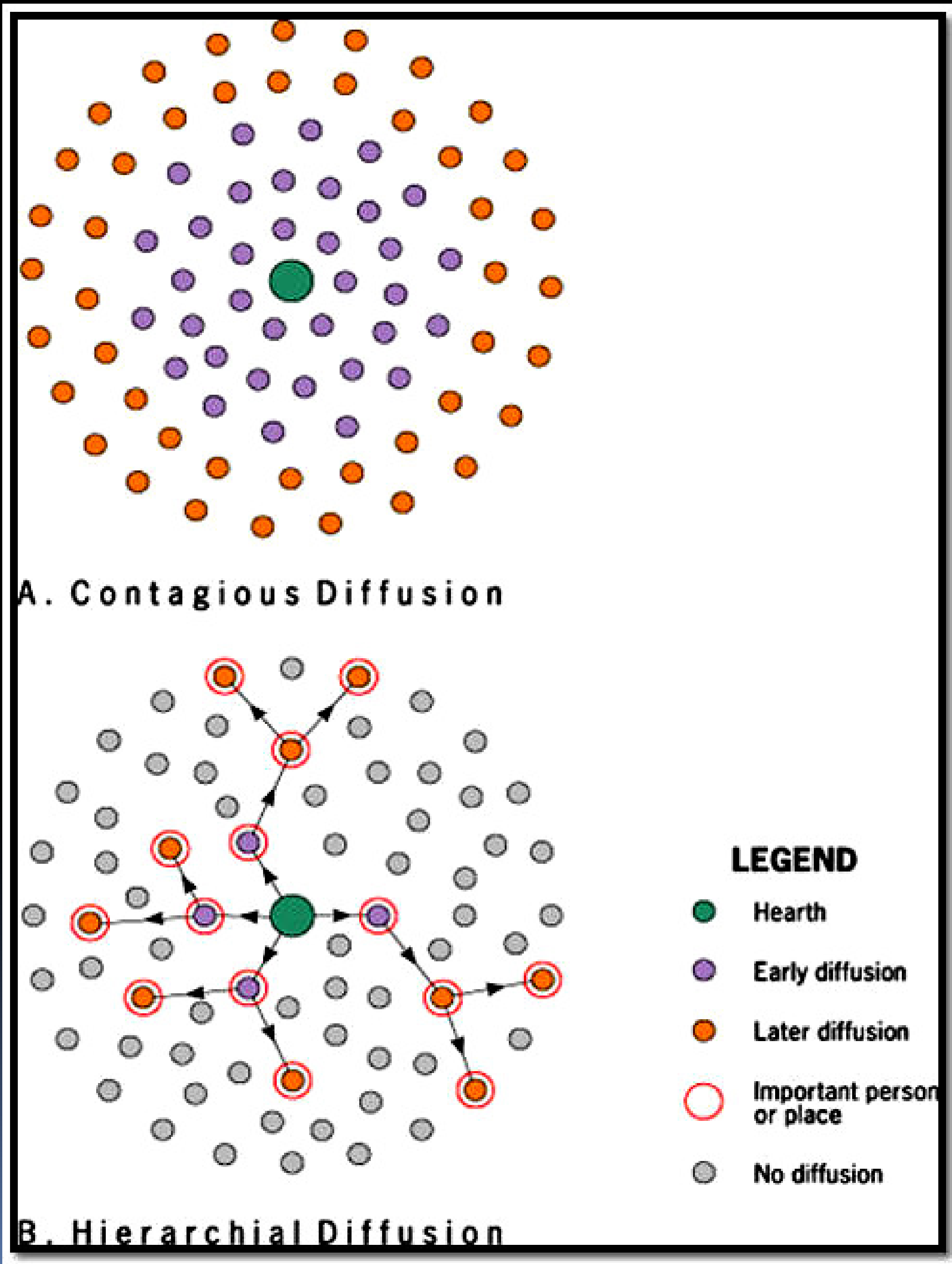
The concept of a phenomenon spreading through geographic space is considered in many studies including those focusing on:

- ✓ **the spread of infectious disease,**
- ✓ **growth of urban centers,**
- ✓ **the diffusion of popular culture and languages (e.g. English)**
- ✓ **Diffusion of sports (e.g. Soccer)**
- ✓ **the spread of wildfires,**
- ✓ **diffusion of innovation (e.g. the industrial revolution),**
- ✓ **ripple effects in the natural world**
- ✓ **political apprising now taking place in the Middle East**

Expansion and relocation diffusion:

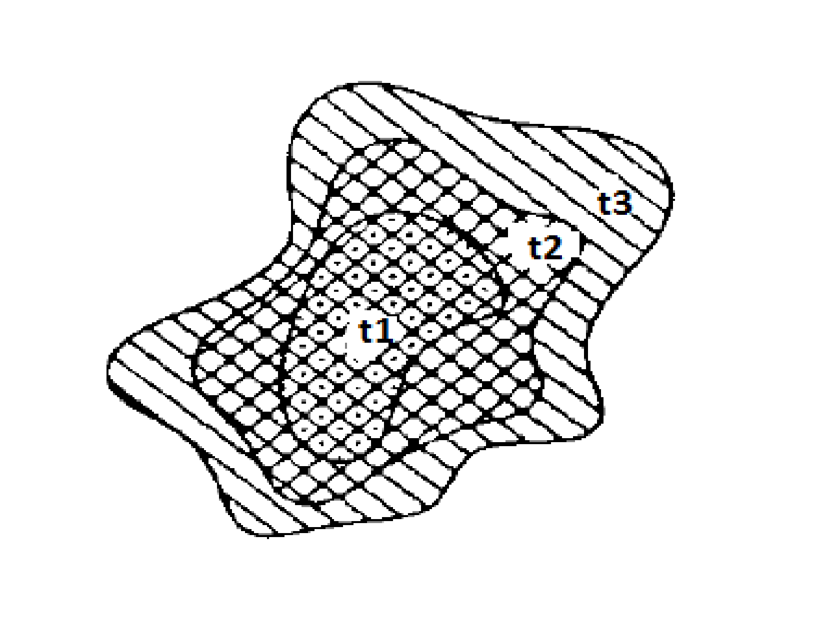
Is the process whereby a phenomenon of interest (this may be information, a material artifact, a disease), spreads from one location to another (often contiguous) location. The spread of a wildfire or diffusion of an innovation are examples of expansion diffusion.

In expansion diffusion (also referred to as **contagious diffusion**), a phenomenon, such as knowledge of an innovation or a disease, is spread by direct contact or word of mouth. This type of diffusion exhibits the **frictional effects of distance** by which those furthest away are less likely to receive this information than those closer to the initial source (distance decay).



- t1, t2, t3 denotes time 1, 2 and 3 respectively

Expansion diffusion

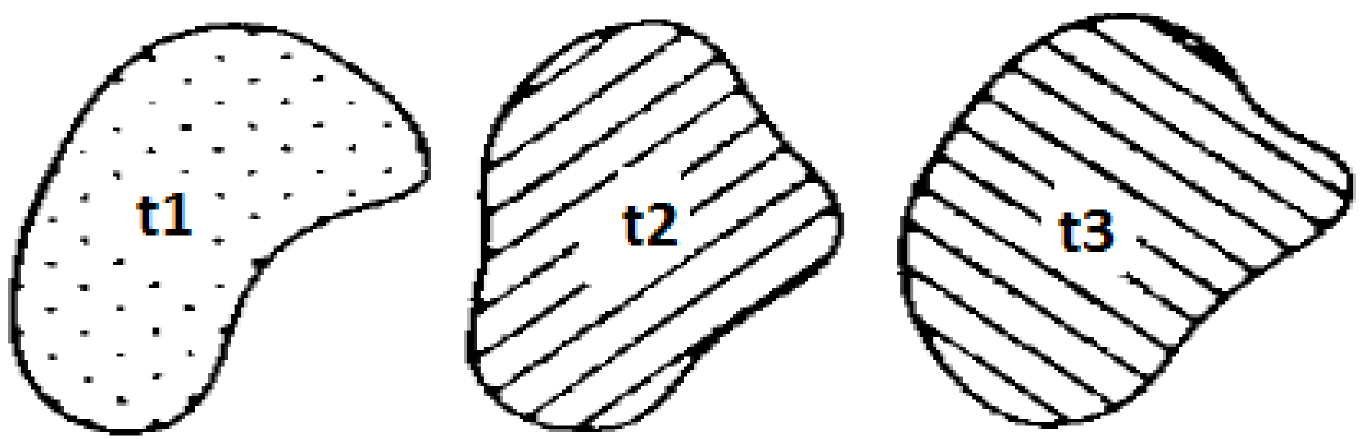


Relocation diffusion

***Relocation diffusion**: is a spatial spread process, but the items being* diffused leave the areas where they originated as they move to new areas.

Relocation diffusion describes the spread that occurs when the spreading phenomena moves into new areas, but leaves behind its origin or source. A common example of relocation diffusion is that of **migration**, for instance the movement of persons from rural to urban areas or the migration of Europeans to North and South America.

In other words, it is a type of diffusion in which **the** items being diffused leave the areas where they originated as they move to new areas.



Contd…..Relocation diffusion

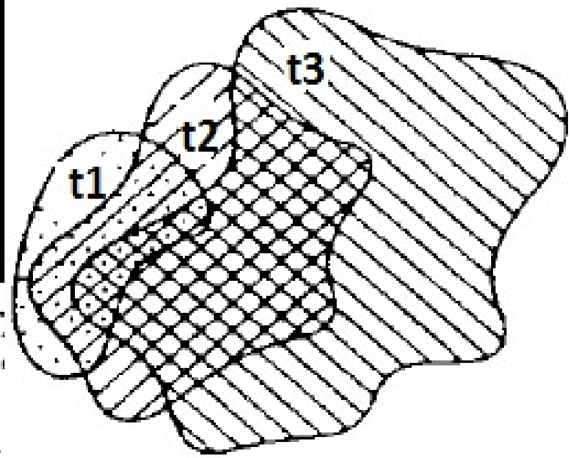
✓**Involves the introduction of an innovation to a new location that is not part of the network of interactions from which it comes.**

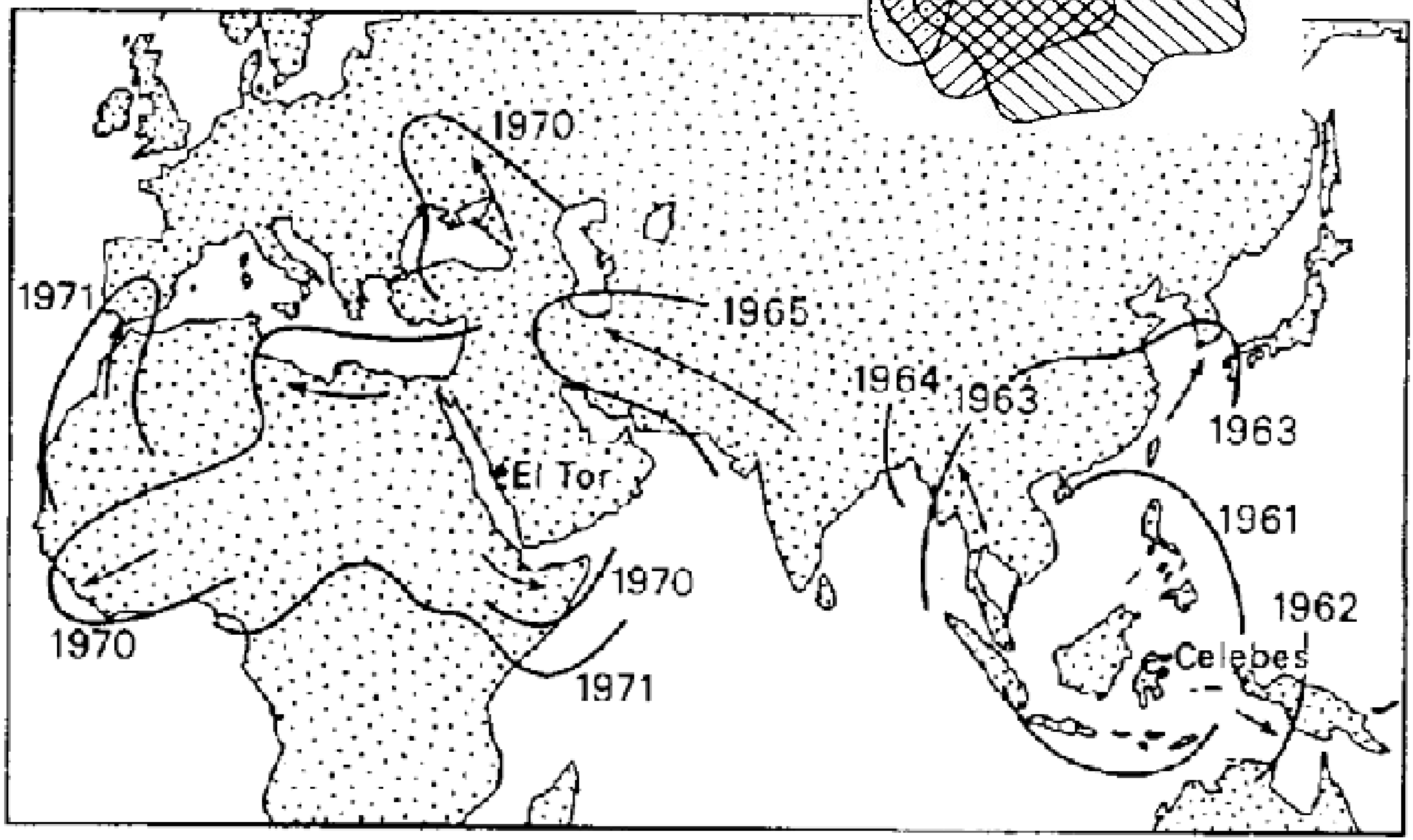
✓**It also involves leaps over great distances and intervening destinations. People with knowledge may migrate to a new place, for example, as when Italian immigrants taught New York Irish Americans to make pizza.**

The movement of plague bacilli from barrowing rodents in central Asia to rodents in European cities barrowing rodents in America, Argentina, and South African grasslands constituted a whole series of relocation diffusions.

Combined expansion/relocation

Example: The spread of the El Tor cholera epidemic, 1960-71





Hierarchical Diffusion

Expansion diffusion occurs in two ways.

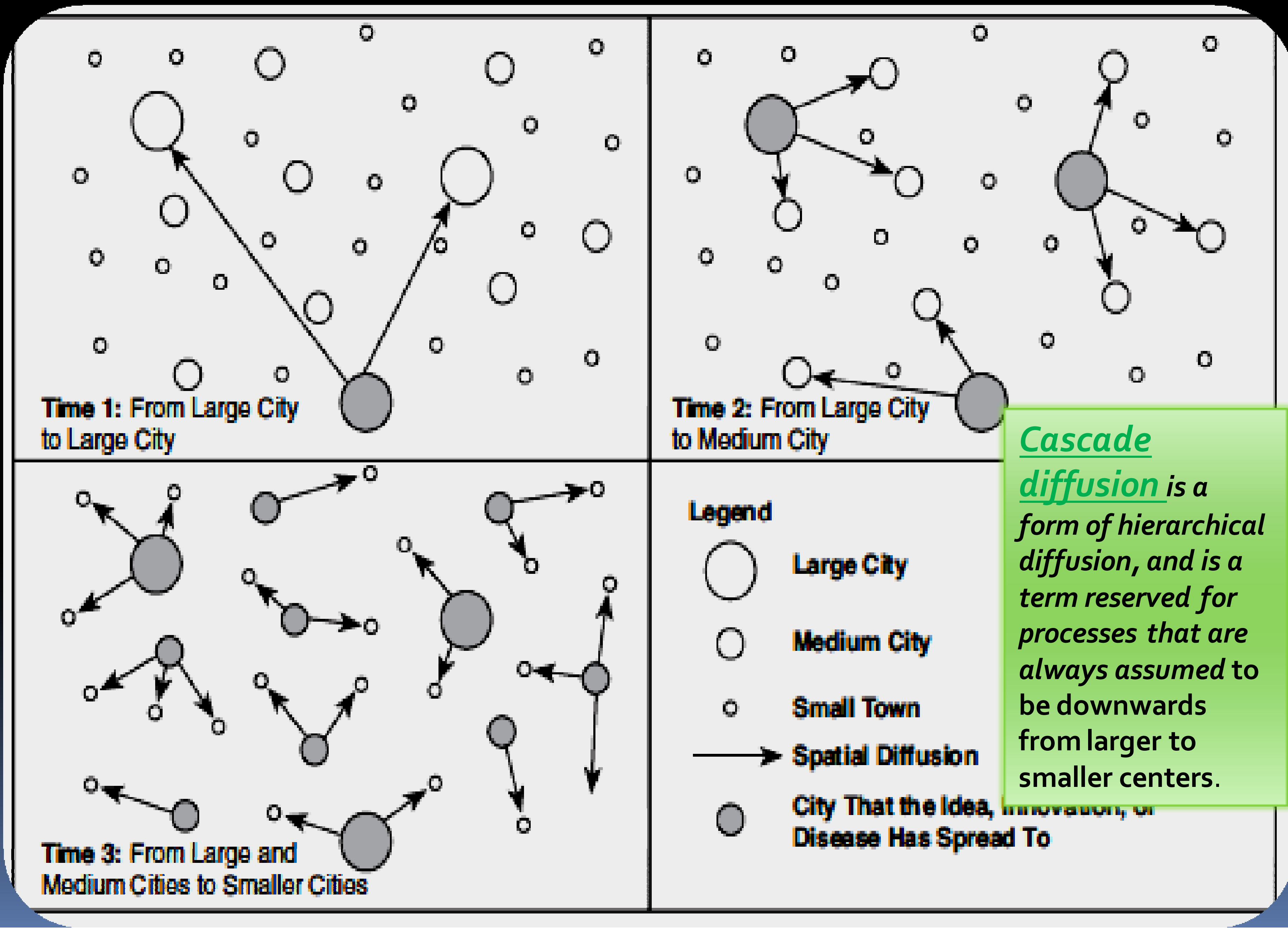
– Contagious spread

– Hierarchical spread

Hierarchical spread involves transmission through an ordered sequence of **classes or places, for example from large metropolitan centers to remote villages.**

For instance, within socially structured populations, innovations may be adopted first on the upper level of the social hierarchy and then trickle down to the lower levels.

Hierarchical diffusion



Cascade diffusion is a form of hierarchical diffusion, and is a term reserved for processes that are always assumed to be downwards from larger to smaller centers.

Stages before and After Diffusion

Torsten Hägerstand (1953) identified four distinct stages in the passage of an innovation through an area:

- ✓**Primary stage**
- ✓**Diffusion stage**
- ✓**Condensing stage**
- ✓**Saturation stage**

The primary stage: marks the beginning of the diffusion process.

✓A **centre of adoption** is established at the origin.

✓There is a strong contrast in the level of adoption between this centre and remote areas which is reflected in the steep decline of the level of adoption curve beyond the origin.

Diffusion Stage:

The diffusion stage signals the start of the actual spread process

- ✓**There is a powerful centrifugal effect, resulting in the rapid growth of acceptance in areas distant from the origin and by a reduction in the strong regional contrasts typical of the primary stage.**
- ✓**This results in a flattening of the slope of the proportion of adopters curve.**

Condensing Stage

In the *condensing stage,* the relative increase in the numbers accepting an item is equal in all locations, regardless of their distance from the original innovation centre

Saturation Stage:

The final *saturation stage* is marked by a slowing and eventual cessation of the diffusion process, which produces a further flattening of the acceptance curve.

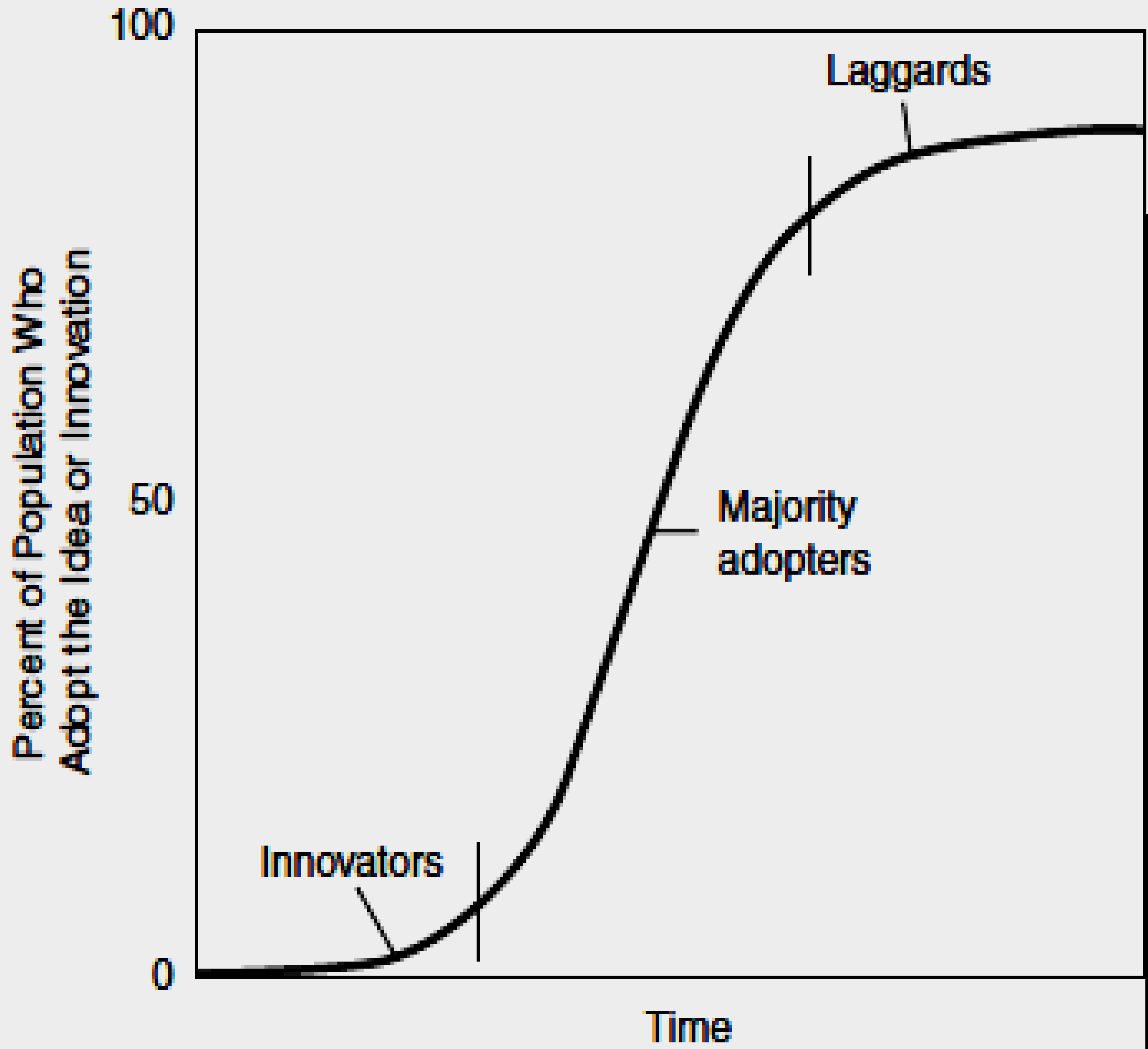
In this stage, the item being diffused has been adopted throughout the country, so that there is very little regional variation.

Modeling Diffusion (five diagrams below)

The shape of the changing diffusion profile in time and space has been formally modeled.

The temporal build-up in the number of adopters of an innovation follows an S-shaped curve (see next slide) when plotted against time, with a logistic curve as the mathematical form most commonly adopted.

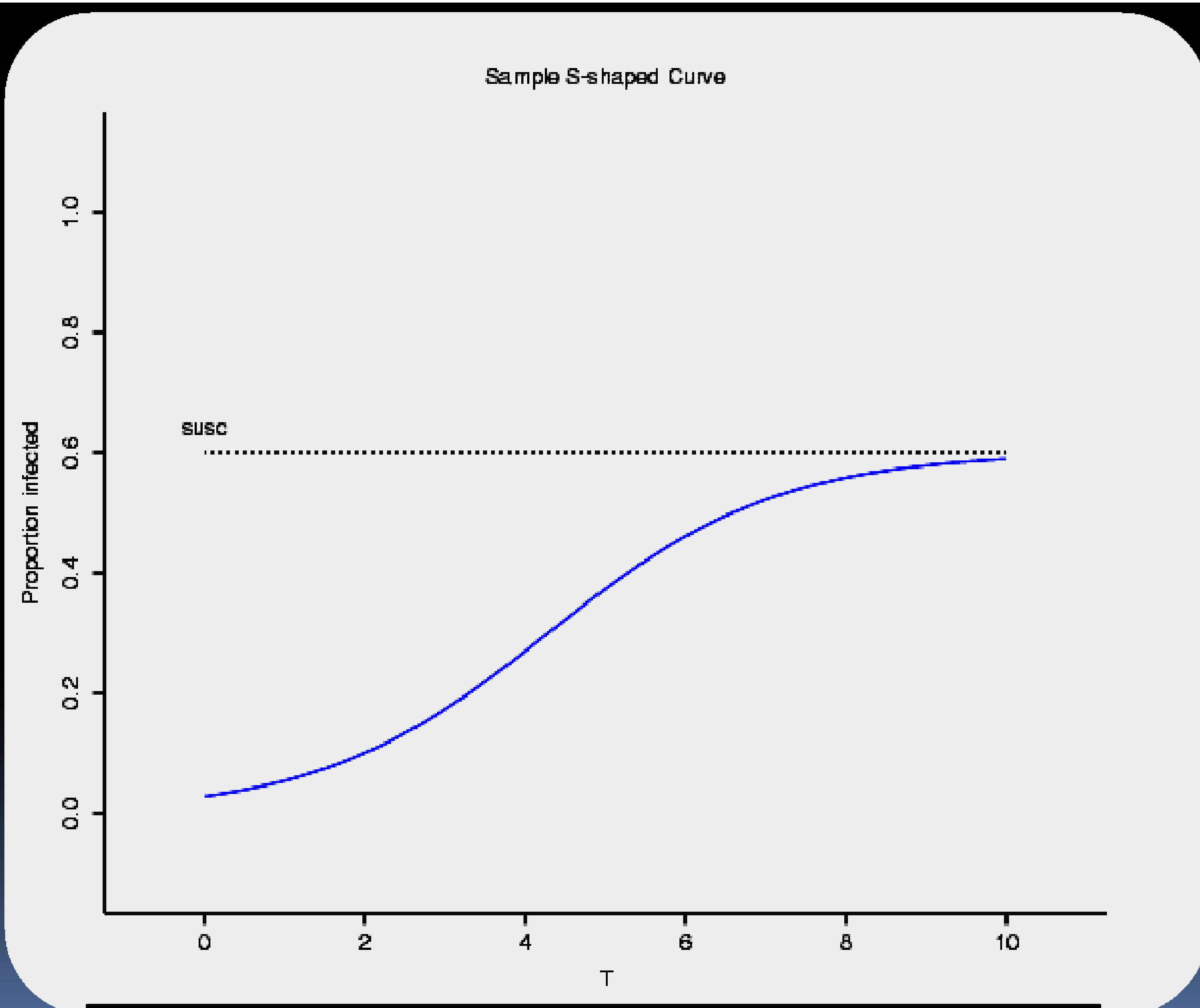
A. The Logistic Curve



http://media.wiley.com/product_data/excerpt/52/04714305/0471430552-3.pdf

The shape of the changing diffusion profile in time and space has been formally modeled.

- The temporal build-up in the number of adopters of an innovation follows an **S-shaped curve** when plotted against time, with a logistic curve as the mathematical form most commonly adopted.



http://www.nku.edu/~longa/modules/leaps/Leaps/leaps.html

✓Generally speaking, such a curve arises because frequently there are few cases when a disease first appears.
✓As people interact in a geographic landscape, the disease diffuses.
✓As more people contract the disease, the number having it while interacting increases.
✓As the number of susceptible people contracting the disease increases, the number of uninfected people must necessarily decrease, since there is a fixed total population inhabiting a given geographic landscape.
✓Hence, as time passes, the chance of a disease carrier interacting with an unexposed person decreases.
✓Therefore, in the beginning, when a disease first appears, the total number of cases begins to increase at an explosive rate.
✓ But at some point in time, when the chance of interacting with an unexposed person is less than the chance of interacting with an exposed person, the rate of increase in the number of cases begins to decrease.
✓Eventually either all, or nearly all, susceptible people are infected, and the disease subsides.

The incubation period for a given communicable disease impacts the steepness of the affiliated S-shaped curve. In addition, natural and artificial immunization, and natural resistance to a disease impacts the percentage of a population that can contract the disease.

This S-shaped curve can be described with the following equation

Proportion of adopters/infected $\mathbf{(P)} =$ U/ 1 + e $^{(a\text{-}bT)}$

Where:

✓**T** denotes the number of time periods since the innovation/disease first appeared.

✓**U** is the upper limit of the adoption/disease occurrence (10 if everyone accepts/becomes sick)

✓The parameter **a** indicates the height above the horizontal T axis of a graph (see previous slide) where the S-shaped curve starts

✓ The parameter **b** indicates how quickly the curve rises.

Because most diseases are preceded by their absence in a geographic landscape, often **a** will be rather large (making the denominator much larger than the numerator, and hence leading to a small value of the quotient). Rapid diffusion will have a very large **b** value; sluggish diffusion will have a **b** value closer to 0. Effective interventions should reduce the percentage of a population that is susceptible, and should reduce the **b** value, causing the curve to have a more shallow slope.

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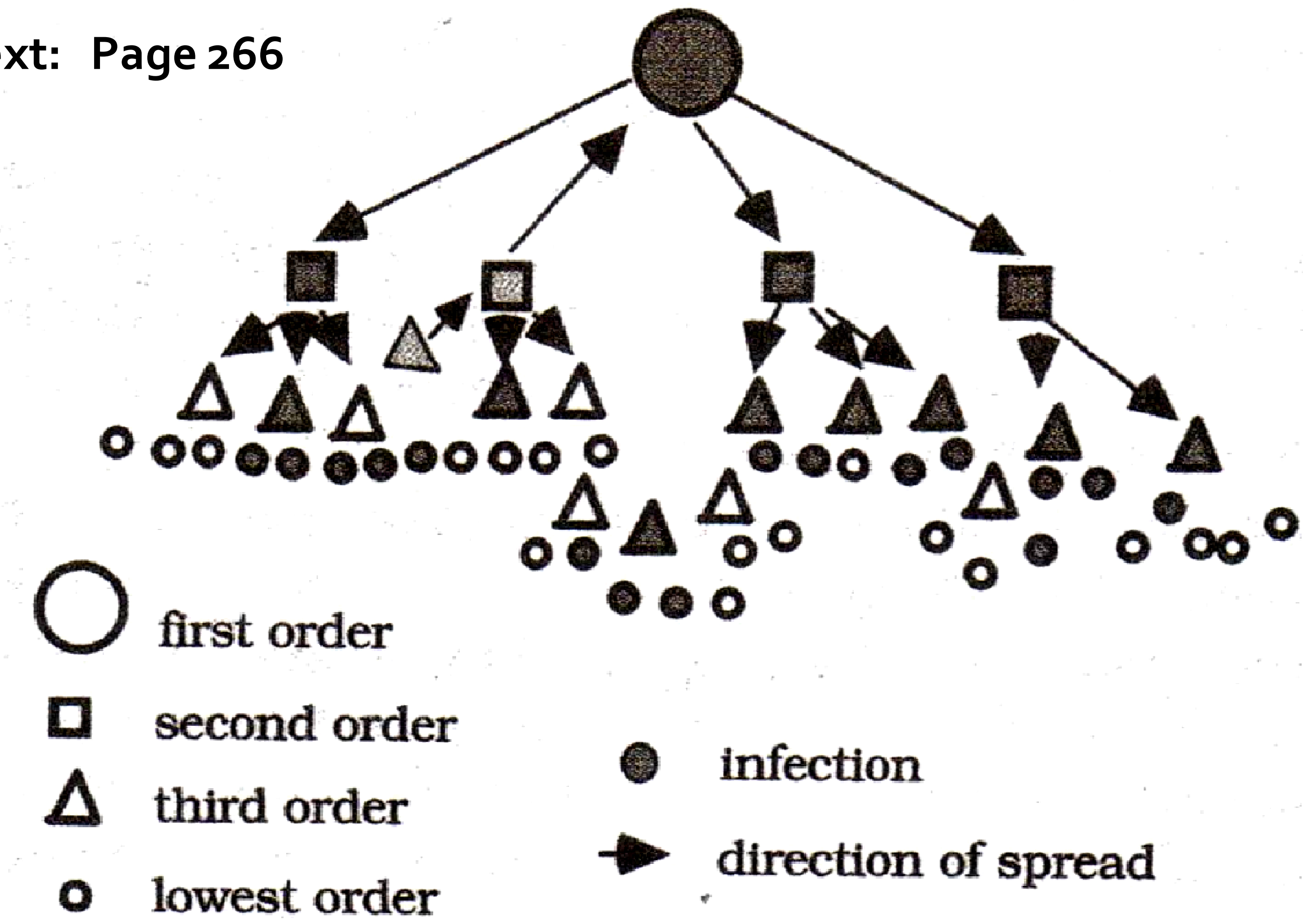

FIGURE 8-1. Infection cascading down the urban hierarchy.

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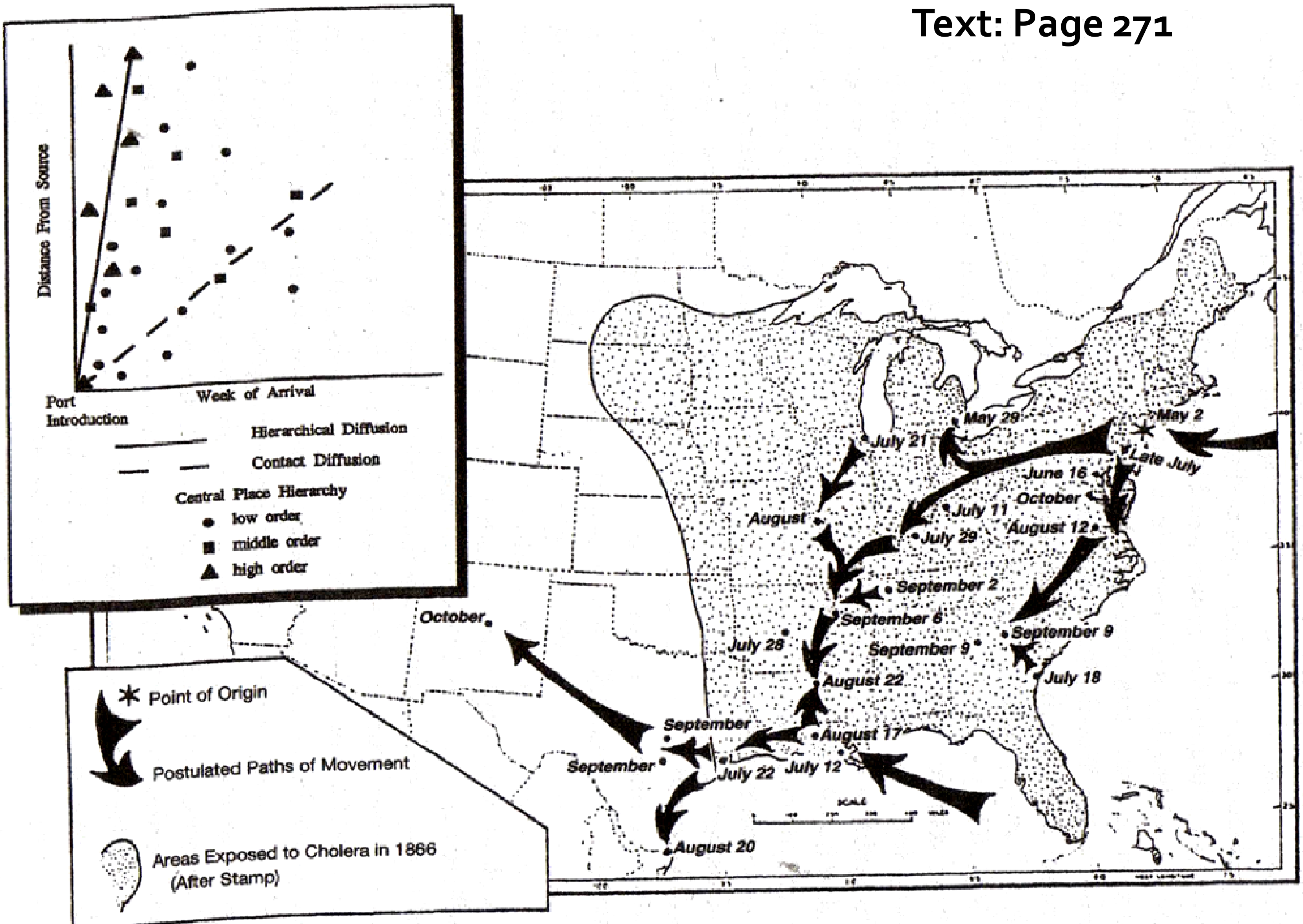

FIGURE 8-3. Diffusion of the 1832 cholera epidemic in the United States. From Pyle (1969, p. 66). Copyright 1969 by Ohio State University Press. Reprinted by permission.

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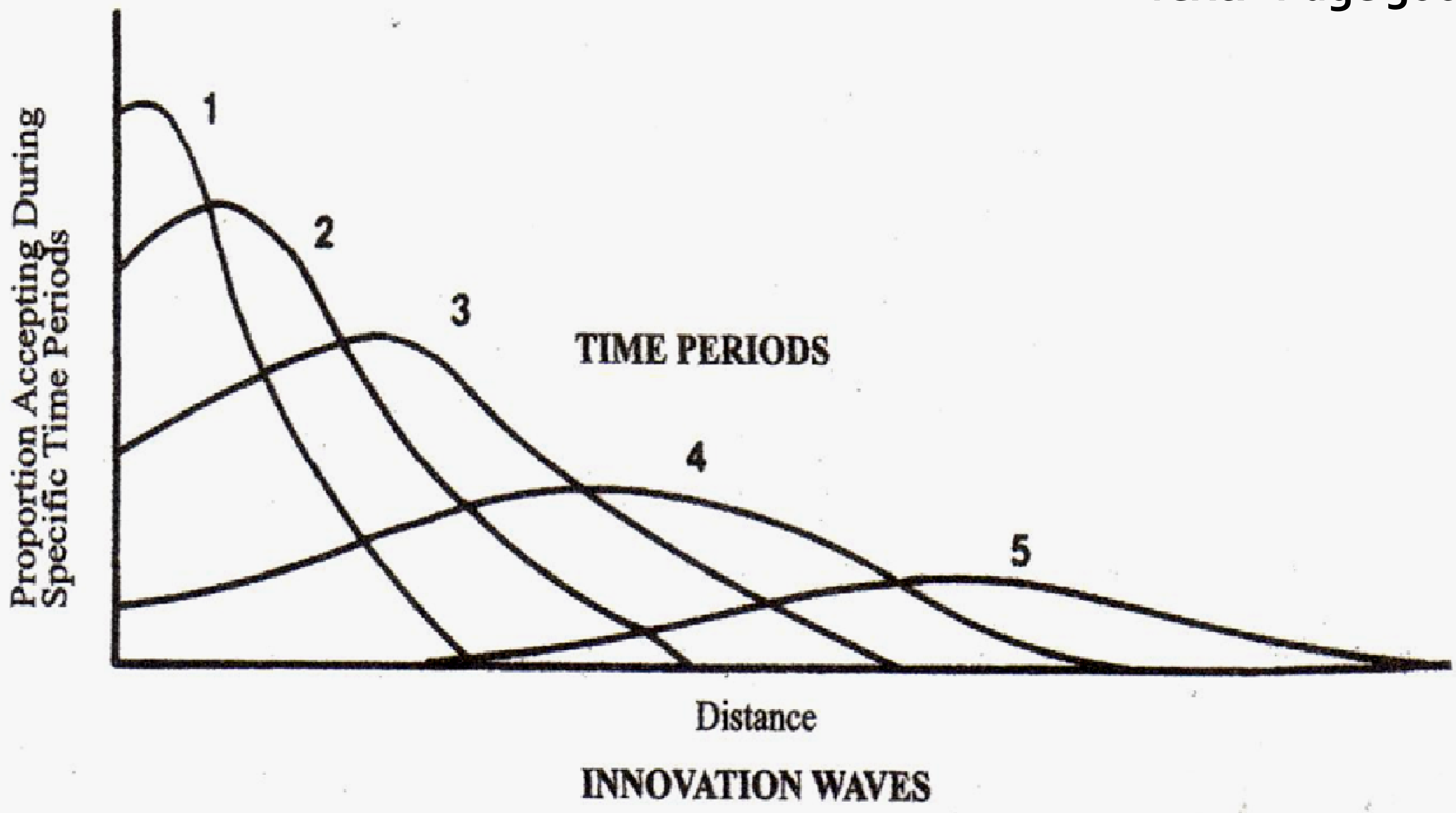

VIGNETTE 8-1, FIGURE 1. Innovation waves. Adapted from Gould (1969, p. 11). Copyright 1969 by Association of American Geographers. Adapted by permission.

N = 10,000

Center of innovation
Probability of acceptance:
approx 45%

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Less than 1%

.0096	.0140	.0168	.0140	.0096
.0140	.0301	.0547	.0301	.0140
.0168	.0547	.4432	.0547	.0168
.0140	.0301	.0547	.0301	.0140
.0096	.0140	.0168	.0140	.0096

VIGNETTE 8-2, FIGURE 1. Mean information field.

More on Diffusion Modeling

- ✓ Diseases are a ubiquitous part of human life.
- ✓ Many, such as the common cold, have minor symptoms and are purely an annoyance; but others, such as Ebola or AIDS, fill us with dread.
- ✓ It is the unseen and seemingly unpredictable nature of diseases, infecting some individuals while others escape, that has gripped our imagination.
- ✓ Over the past one hundred years, mathematics has been used to understand and predict the spread of diseases, relating important public-health questions to basic infection parameters.

- ✓The mathematics of diseases is, of course, a data-driven subject.
- ✓Although some purely theoretical work has been done, the key element in this field of research is being able to link mathematical models and data.
- ✓Case reports from doctors provides us with one of the most detailed sources of biological data; we often know the number of weekly disease cases for a variety of communities over many decades.
- ✓This data also contains the signature of social effects, such as changes in birth rate or the increased mixing rates during school terms. Therefore, a comprehensive picture of disease dynamics requires a variety of mathematical tools, from model creation to solving differential equations to statistical analysis.

B. The SIR model

The SIR model

• Almost all mathematical models of diseases start from the same basic premise: that the population can be subdivided into a set of distinct classes, dependent upon their experience with respect to the disease.

• The simplest of these models classify individuals as one of **susceptible (S), infectious (I) or recovered (R). This is termed the SIR model.**

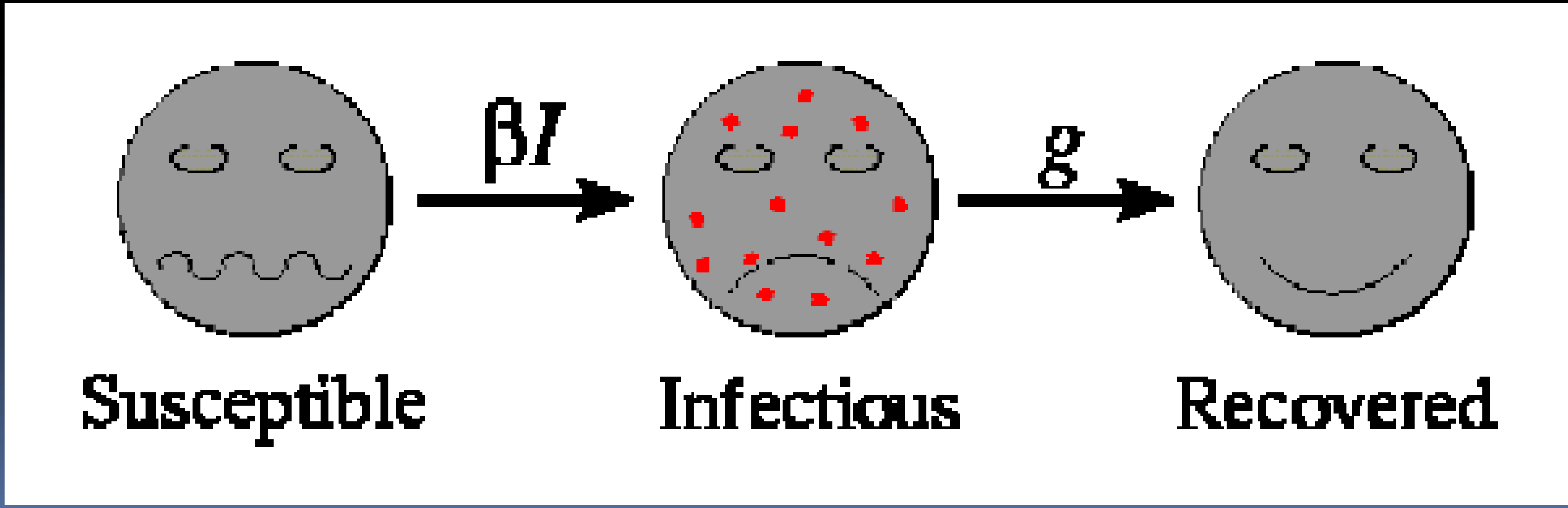
✓ Individuals are born into the susceptible class.

✓ Susceptible individuals have never come into contact with the disease and are able to catch the disease, after which they move into the infectious class.

✓ Infectious individuals spread the disease to susceptibles, and remain in the infectious class for a given period of time (the infectious period) before moving into the recovered class.

✓ Finally, individuals in the recovered class are assumed to be immune for life.

✓ We can make this description more mathematical by formulating a differential equation for the proportion of individuals in each class.



Barriers to Diffusion

✓Diffusion occurs over a wide web, or network of places, people, as well as the communication links through which information, people, and goods flow.

✓In opposition to networks which channel and support diffusion, barriers slow and shape the process.

✓Barriers are often physical – oceans, deserts, mountains, rivers, etc. or cultural. Rapid transport today has almost eliminated the effectiveness of physical barriers while globalization is eroding the protective effects of cultural barriers.

Types of Barriers:

Absorbing barriers*: *Stop the diffusion process

Population vaccinated against smallpox were an example of an absorbing barrier. Also when a small population size and/or density does not facilitate contact transmission.

Reflecting barriers*: *Channel and intensify the local impact of a diffusion process while blocking its spread to another locale. Example: the presence of lake or un-bridged river, hostile ethnic group or gang.

Permeable barriers*: *allowing some diffusion but slowing the process.

Most international borders are permeable barriers.