Factors Affecting Foodborne Disease

Types of Foodborne Disease

- Infection
  - Foodhandler
  - Food Concentration
  - Direct Contamination
  - Water-washed
- Toxico-infection
- Intoxication (food poisoning)
  - Bacterial and Fungal Toxins
  - Shellfish Toxins
  - Metals, Chemicals, etc.
- Allergy

TABLE 1. Number of reported foodborne-disease outbreaks, cases, and deaths, by etiology — United States,* 1993–1997†

Etiology	Outbreaks		Cases		Deaths	
	No.	(%)	No.	(%)	No.	(%)
Confirmed etiology	878	(31.9)	50,788	(59.0)	28	(96.6)
Unknown etiology	1,873	(68.1)	35,270	(41.0)	1	(3.4)
Total 1993–1997	**2,751**	**(100.0)**	**86,058**	**(100.0)**	**29**	**(100.0)**

*Includes Guam, Puerto Rico, and the U.S. Virgin Islands.
†Totals might vary by <1% from summed components because of rounding.

Table 3. Estimated illnesses, hospitalizations, and deaths caused by known foodborne pathogens, United States

Disease or agent	Illnesses			Hospitalizations			Deaths		
	Total	Food-borne	% of total foodborne	Total	Food-borne	% of total foodborne	Total	Food-borne	% of total foodborne
Bacterial									
Bacillus cereus	27,360	27,360	0.2	8	8	0.0	0	0	0.0
Botulism, foodborne	58	58	0.0	46	46	0.1	4	4	0.2
Brucella spp.	1,554	777	0.0	122	61	0.1	11	6	0.3
Campylobacter spp.	2,453,926	1,963,141	14.2	13,174	10,539	17.3	124	99	5.5
Clostridium perfringens	248,520	248,520	1.8	41	41	0.1	7	7	0.4
Escherichia coli O157:H7	73,480	62,458	0.5	2,168	1,843	3.0	61	52	2.9
E. coli, non-O157 STEC	36,740	31,229	0.2	1,084	921	1.5	30	26	1.4
E. coli, enterotoxigenic	79,420	55,594	0.4	21	15	0.0	0	0	0.0
E. coli, other diarrheogenic	79,420	23,826	0.2	21	6	0.0	0	0	0.0
Listeria monocytogenes	2,518	2,493	0.0	2,322	2,298	3.8	504	499	27.6
Salmonella typhi	824	659	0.0	618	494	0.8	3	3	0.1
Salmonella, nontyphoidal	1,412,498	1,341,873	9.7	16,430	15,608	25.6	582	553	30.6
Shigella spp.	448,240	89,648	0.6	6,231	1,246	2.0	70	14	0.8
Staphylococcus food poisoning	185,060	185,060	1.3	1,753	1,753	2.9	2	2	0.1
Streptococcus, foodborne	50,920	50,920	0.4	358	358	0.6	0	0	0.0
Vibrio cholerae, toxigenic	54	49	0.0	18	17	0.0	0	0	0.0
V. vulnificus	94	47	0.0	86	43	0.1	37	18	1.0
Vibrio, other	7,880	5,122	0.0	99	65	0.1	20	13	0.7
Yersinia enterocolitica	96,368	86,731	0.6	1,228	1,105	1.8	3	2	0.1
Subtotal	5,204,934	4,175,565	30.2	45,826	36,466	59.9	1,458	1,297	71.7
Parasitic									
Cryptosporidium parvum	300,000	30,000	0.2	1,989	199	0.3	66	7	0.4
Cyclospora cayetanensis	16,264	14,638	0.1	17	15	0.0	0	0	0.0
Giardia lamblia	2,000,000	200,000	1.4	5,000	500	0.8	10	1	0.1
Toxoplasma gondii	225,000	112,500	0.8	5,000	2,500	4.1	750	375	20.7
Trichinella spiralis	52	52	0.0	4	4	0.0	0	0	0.0
Subtotal	2,541,316	357,190	2.6	12,010	3,219	5.3	827	383	21.2
Viral									
Norwalk-like viruses	23,000,000	9,200,000	66.6	50,000	20,000	32.9	310	124	6.9
Rotavirus	3,900,000	39,000	0.3	50,000	500	0.8	30	0	0.0
Astrovirus	3,900,000	39,000	0.3	12,500	125	0.2	10	0	0.0
Hepatitis A	83,391	4,170	0.0	10,841	90	0.9	83	4	0.2
Subtotal	30,833,391	9,282,170	67.2	123,341	21,167	34.8	433	129	7.1
Grand Total	38,629,641	13,814,924	100.0	181,177	60,854	100.0	2,718	1,809	100.0

Ingredients

Air

Water

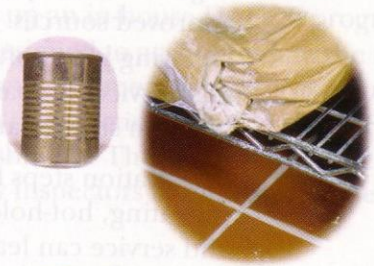
Sources of Food Contamination

Soil

Food Contact Surfaces

Food Handlers

Animals, Rodents, and Insects



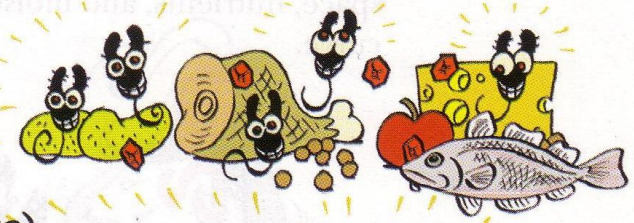
Packaging Materials

Microbial Growth in Food

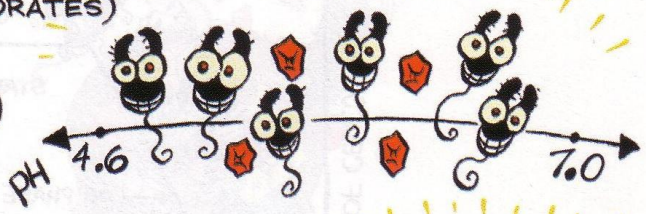
- Bacteria and Fungi
- Complex Ecology
  - Interaction with multiple environmental factors controls whether an organism can grow in a given environment
- Food Preservation
  - Ecology of zero growth

FOOD

(HIGH IN PROTEIN
OR CARBOHYDRATES)



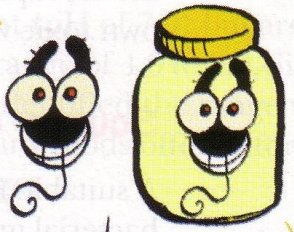
ACID



TEMPERATURE

TIME

OXYGEN



(DEPENDING ON THE TYPE OF BACTERIA,
SOME CAN SURVIVE ONLY WITH OXYGEN,
SOME ONLY WITHOUT OXYGEN,
SOME WITH OR WITHOUT OXYGEN,
SOME WITH OXYGEN IN VERY LIMITED AMOUNTS.)

MOISTURE

(WATER ACTIVITY GREATER THAN 0.85)

Microbial Growth in Food

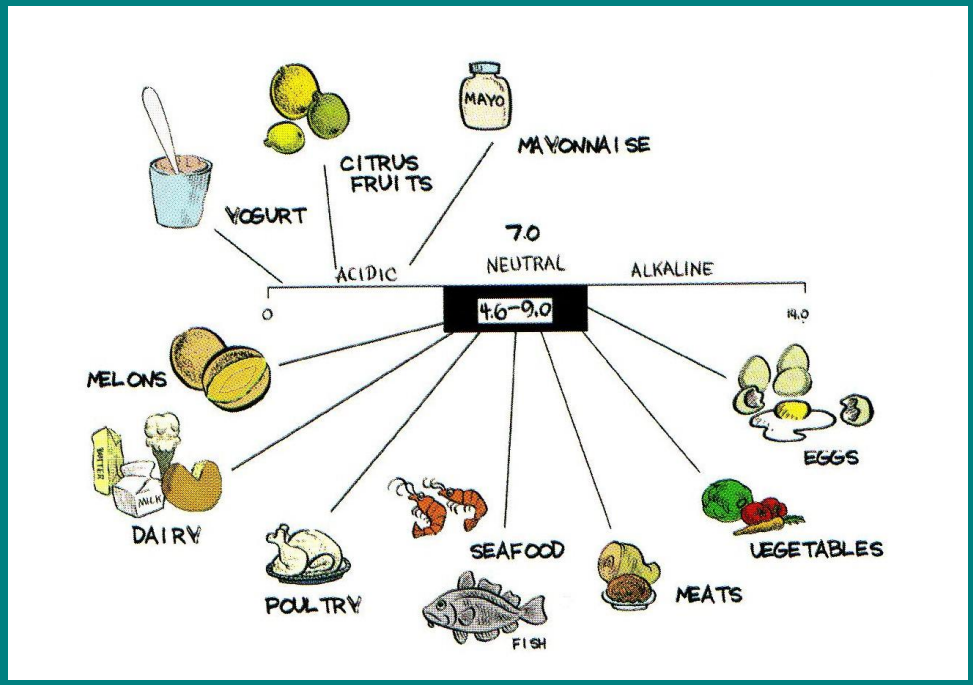
- *Intrinsic Factors*:
  - pH
  - Water Activity
  - Salt Concentration
  - Nutrients
  - Etc.
- *Extrinsic Factors*
  - Temperature
  - Gaseous Conditions
  - Presence of Other Microbes

Heterogeneity

- Question of scale
- Food items may have several distinct microenvironments

pH

- Influences genes encoding carboxylases, lactate dehydrognease, outer membrane proteins, and virulence factors
- Cells sense change in pH by various mechanisms (e.g. protonation/deprotonation of amino acids)

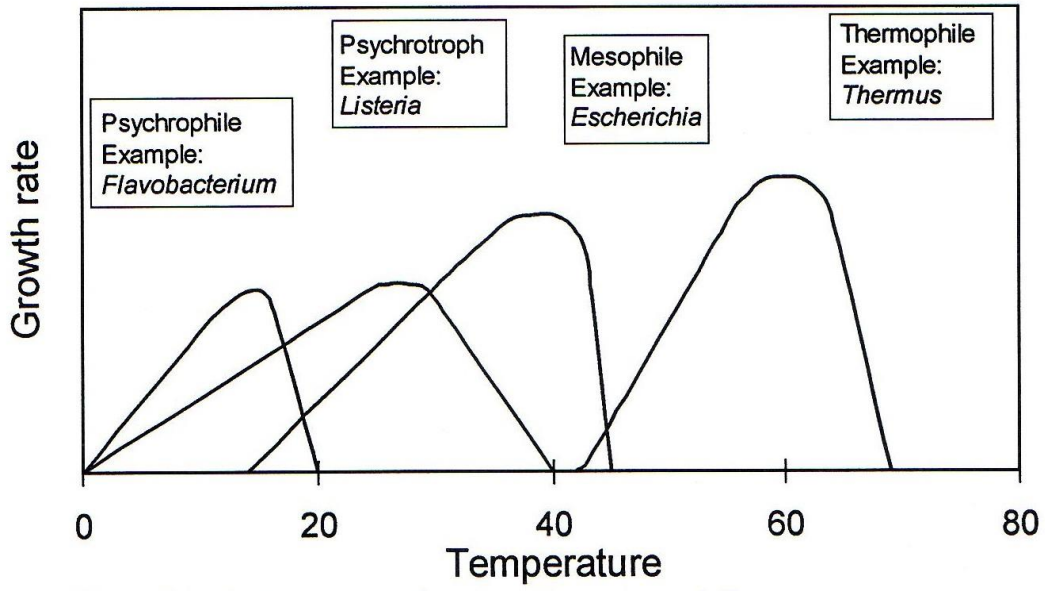


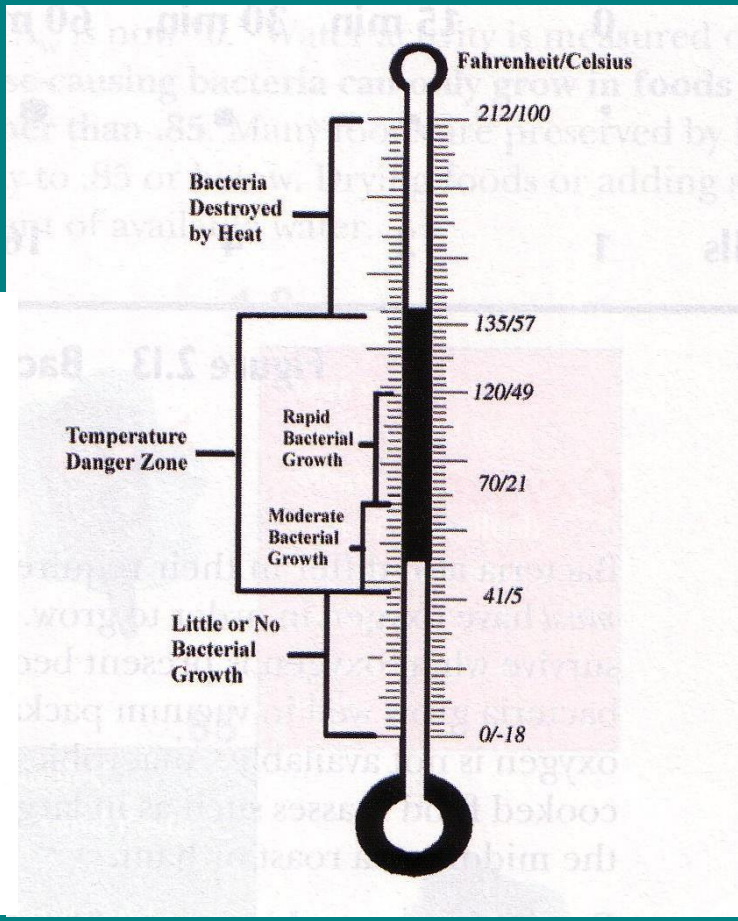
pH

- Two pHs are important: external and internal
- Cells must maintain internal pH to maintain viability thus redundant mechanisms for pH maintenance: for example in *S.enterica*
  - Homeostatic response (allosteric regulation of proton pumps etc.)
  - Acid tolerance response (membrane –bound ATPase proton pumps)
  - Acid shock proteins (synthesis of regulatory proteins triggered by low pH, e.g. DNA binding proteins)

Temperature

- Affects growth kinetics and gene expression (e.g. motility to virulence)

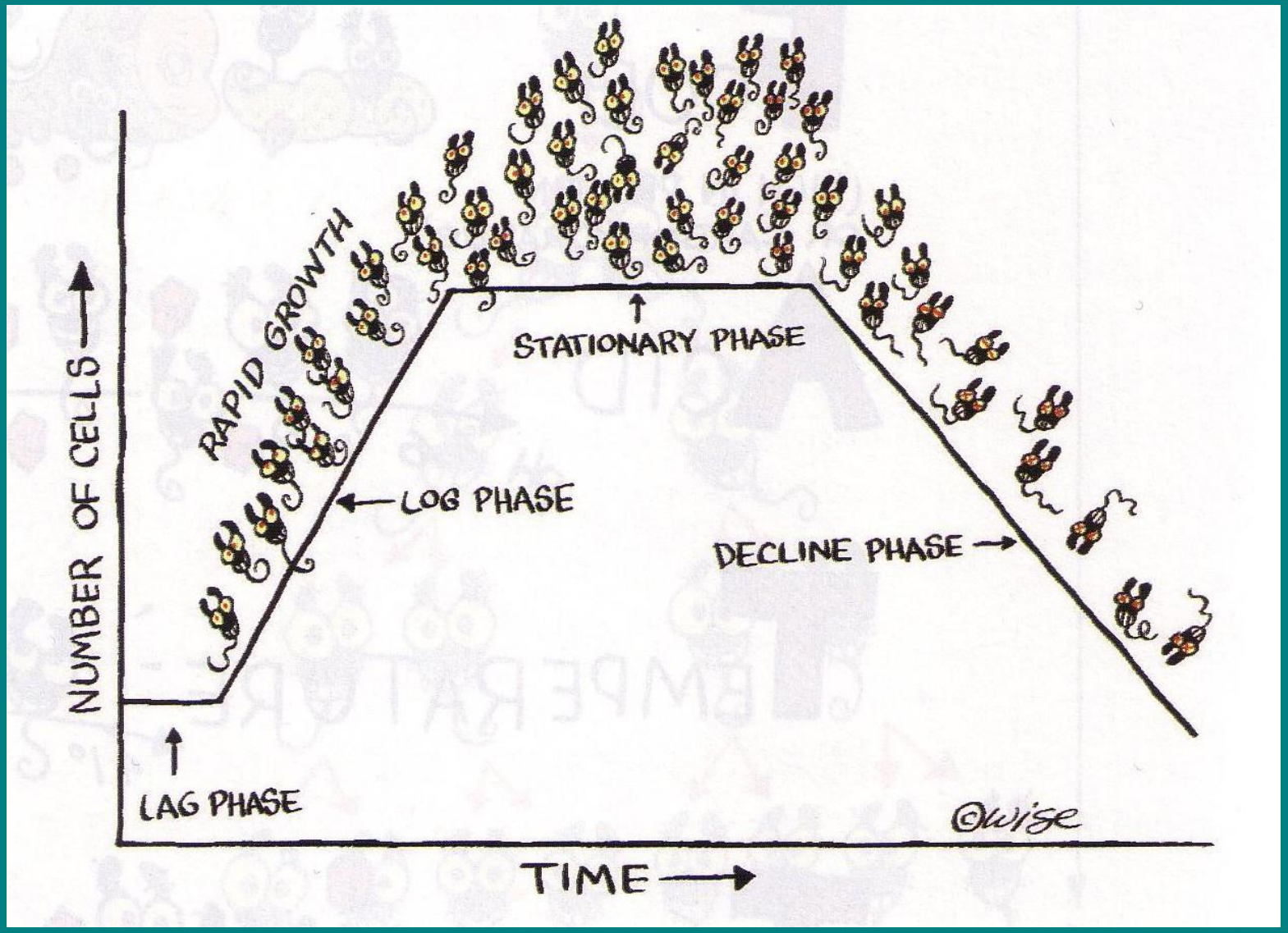




Quorum Sensing

- Cell to Cell Communication
- Release of autoinducers that trigger repression or stimulus of target genes
  - Control of metabolism
  - Control of sporulation
  - Control of spore germination
  - Control of formation of biofilm
  - Control of virulence factors (e.g. toxins)

Microbial Growth and Death



Microbial Growth/Survival in Foods

- Log phase growth and many types of lethality follow first order or pseudo-first order kinetics.
- *D*-values and *z*-values are first order constants
  - *D*-value is the time required to reduce a population by 90%
  - *z*-value is the number of degrees (f) needed to change *D* by factor of 10

First Order Kinetics

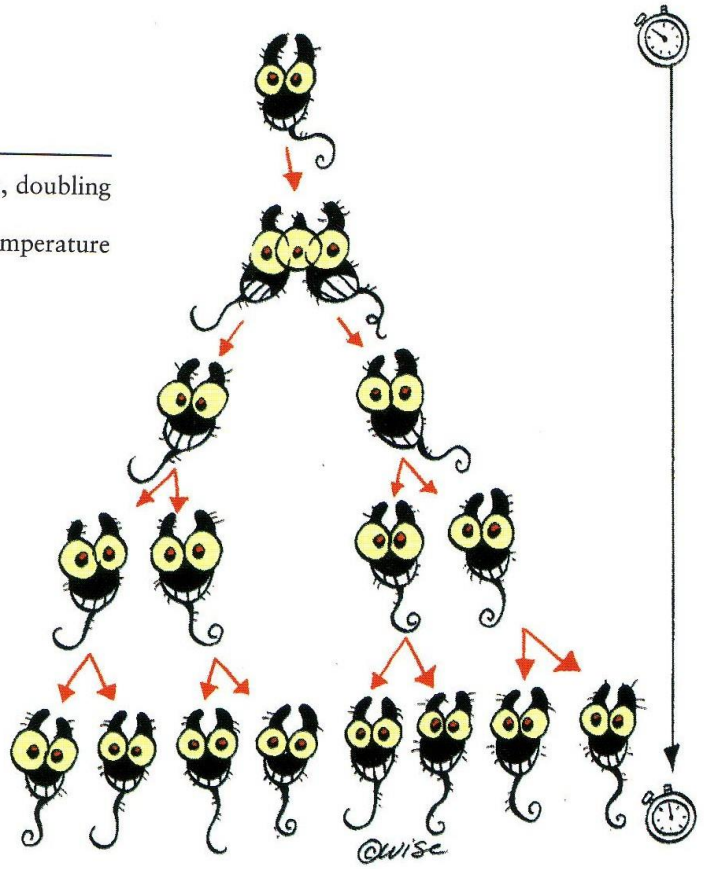
Table 2.1 First-order kinetics can be used to describe exponential growth and inactivation

Growth[a]	Thermal inactivation[b]	Irradiation[c]
1a. $N = N_o e^{\mu t}$	1b. $N = N_o e^{-kt}$	1c. $N = N_o e^{-D/D_o}$
2a. $2.3\log(N/N_o) = \mu \Delta t$	2b. $2.3\log(N/N_o) = -(k\Delta t)$	
3a. $\Delta t = [2.3\log(N/N_o)]/\mu$	3b. $\Delta t = -[2.3\log(N/N_o)]/k$	
4a. $t_d = 0.693/\mu$	4b. $D = 2.3/k$	
	5b. $E_a = \frac{2.3RT_1T_2}{Z} \times \frac{9}{5}$	

[a] N, cell number (CFU/g); N_o, initial cell number (CFU/g); t, time (h); μ, specific growth rate (h^{-1}); t_d, doubling time (h).

[b] k, rate constant (h^{-1}); D, decimal reduction time (h); E_a, activation energy (kcal/mol); T_1 T_2, reference temperature and test temperature (Kelvin).

[c] D_o, rate constant (h^{-1}); D, dose (Gy).



Quantification of Bacteria

- Calculation of Titer (i.e. #/vol or #/mass)
- Calculation of Growth
  - $N_t = N_0 \text{ X } 2^n$
  - $\log N_t = \log N_0 + n \text{ X } \log 2$
- Number of Generations
  - $n = (\log N_t - \log N_0)/0.301$
- Calculation of Log Reduction
  - Log10 reduction = $-\log (N_0 / N_t)$

Injury and Viable But Non-Culturable (VBNC)

- Injured cells or cells in a resting state
- Cells must repair or "turn on" before they will actively grow
- VBNC typically caused thought to be triggered by low nutrient environment; but can be induced by changes in salt concentration, temperature or other stresses

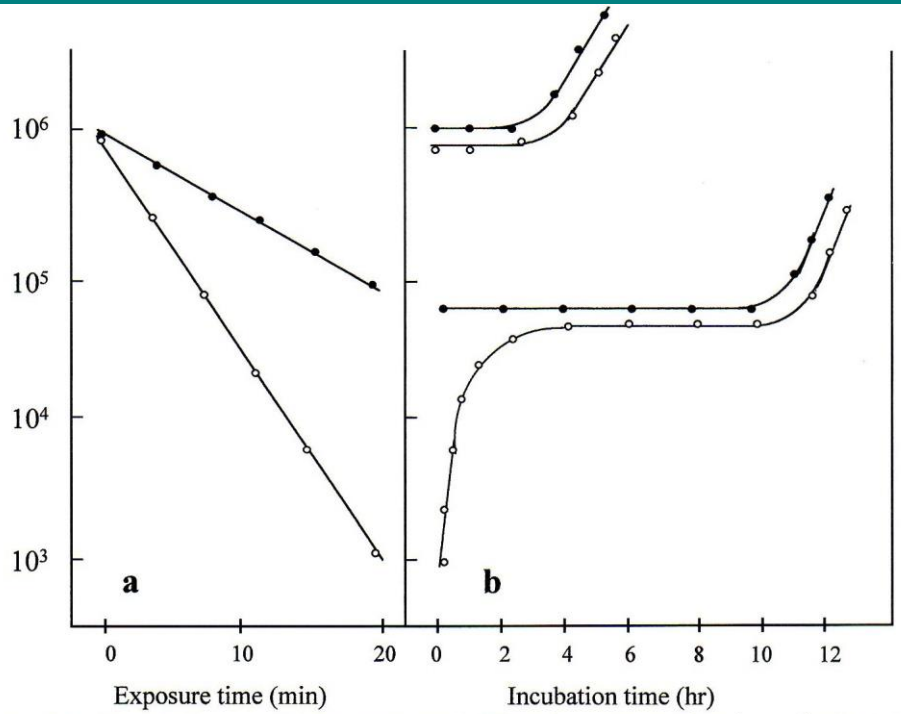
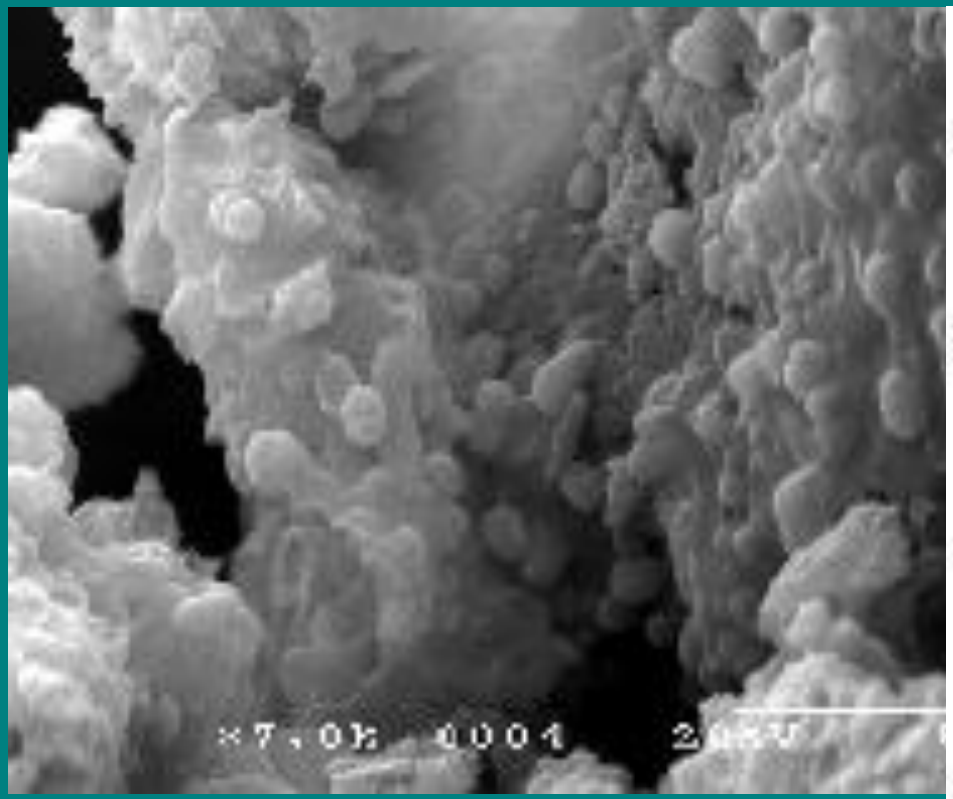
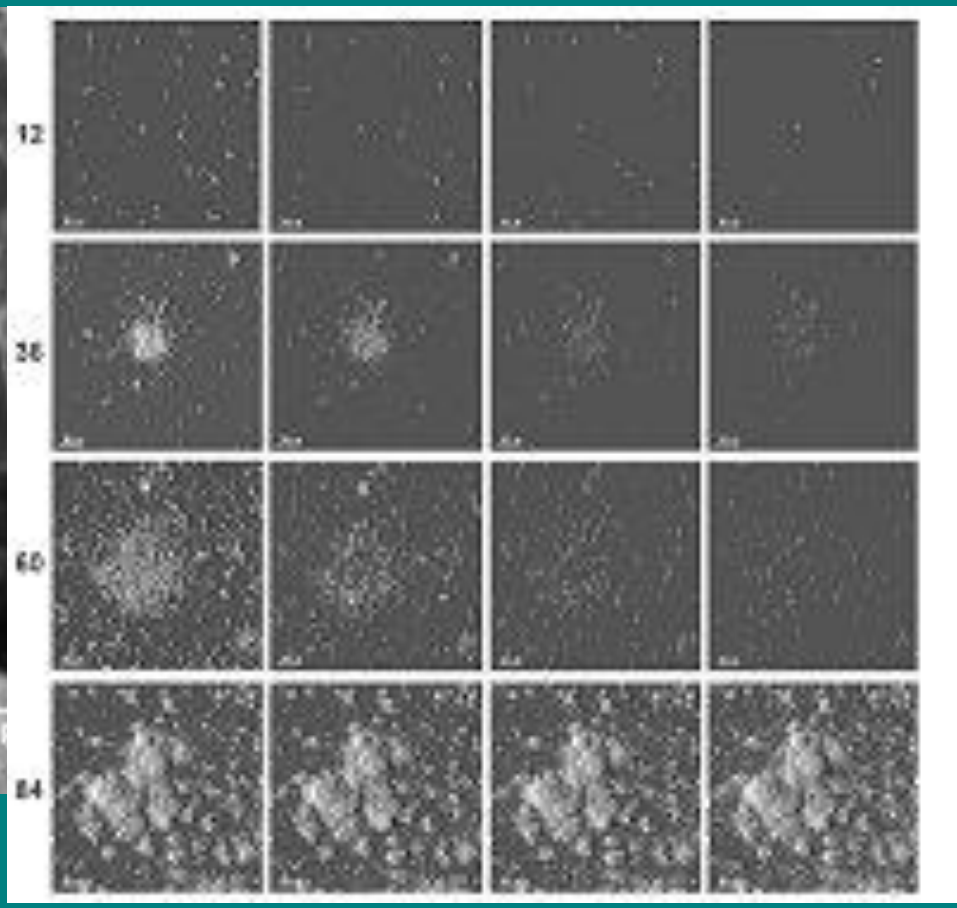
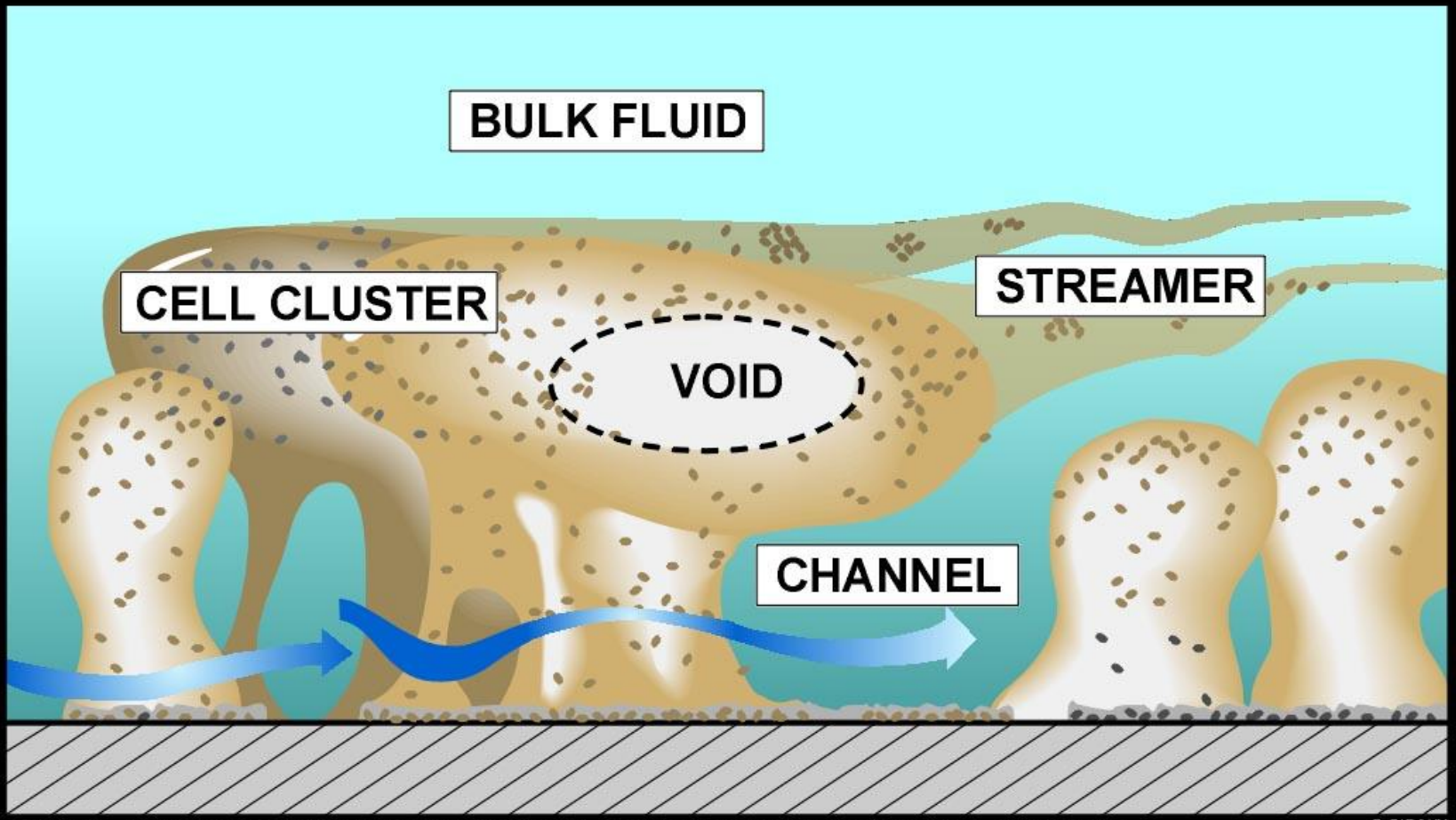


Figure 2.5 Data indicative of injury and repair. When bacteria are plated on selective (○) or nonselective (●) media during exposure to some stressor (a) (e.g., heat), the decrease in CFU on a nonselective medium represents the true lethality, while the difference between the values obtained on each medium is defined as "injury." During "repair" (b) resistance to selective agents is regained, and the value obtained on the selective medium approaches that of the nonselective medium. Unstressed controls are shown on the top of panel b. Modified and redrawn from reference 11.

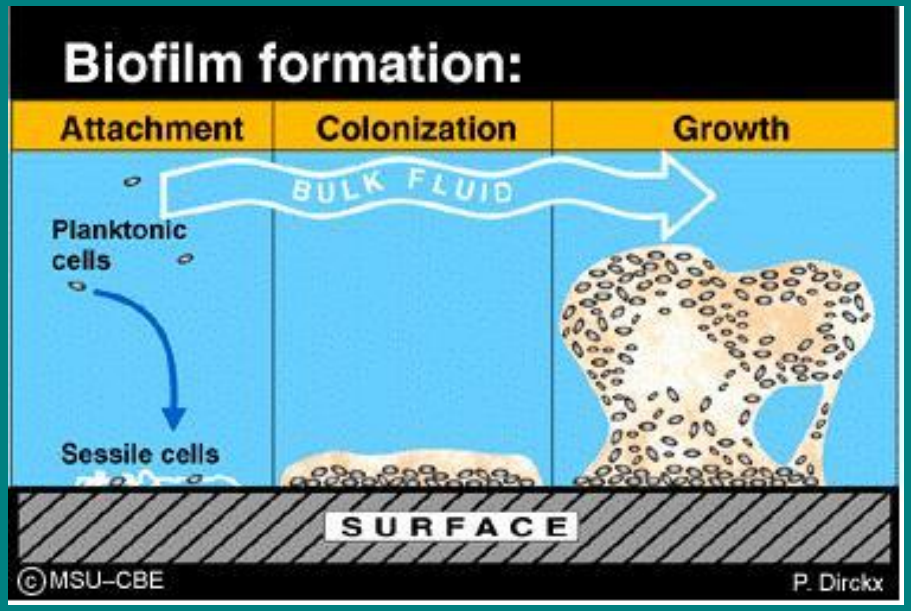
Biofilms

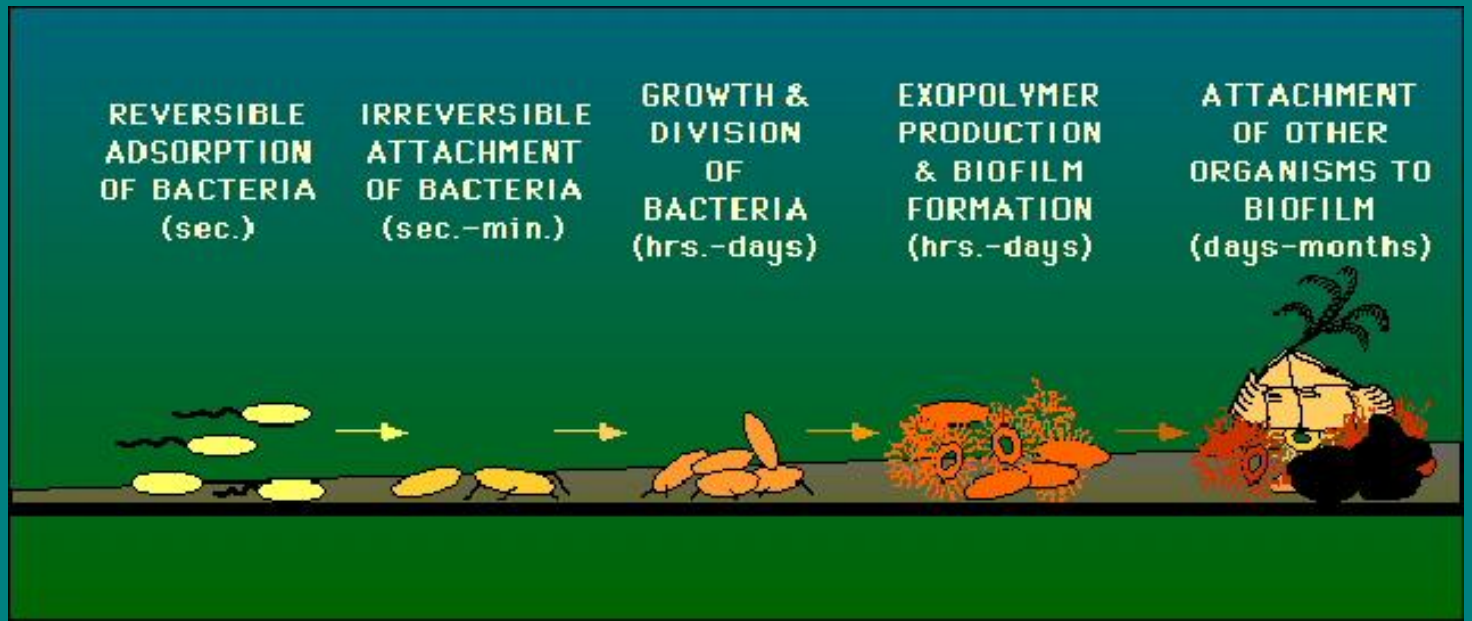





BULK FLUID
CELL CLUSTER
STREAMER
VOID
CHANNEL
© 1996 CENTER FOR BIOFILM ENGINEERING MONTANA STATE UNIVERSITY–BOZEMAN
P. DIRCKX

Biofilm Formation



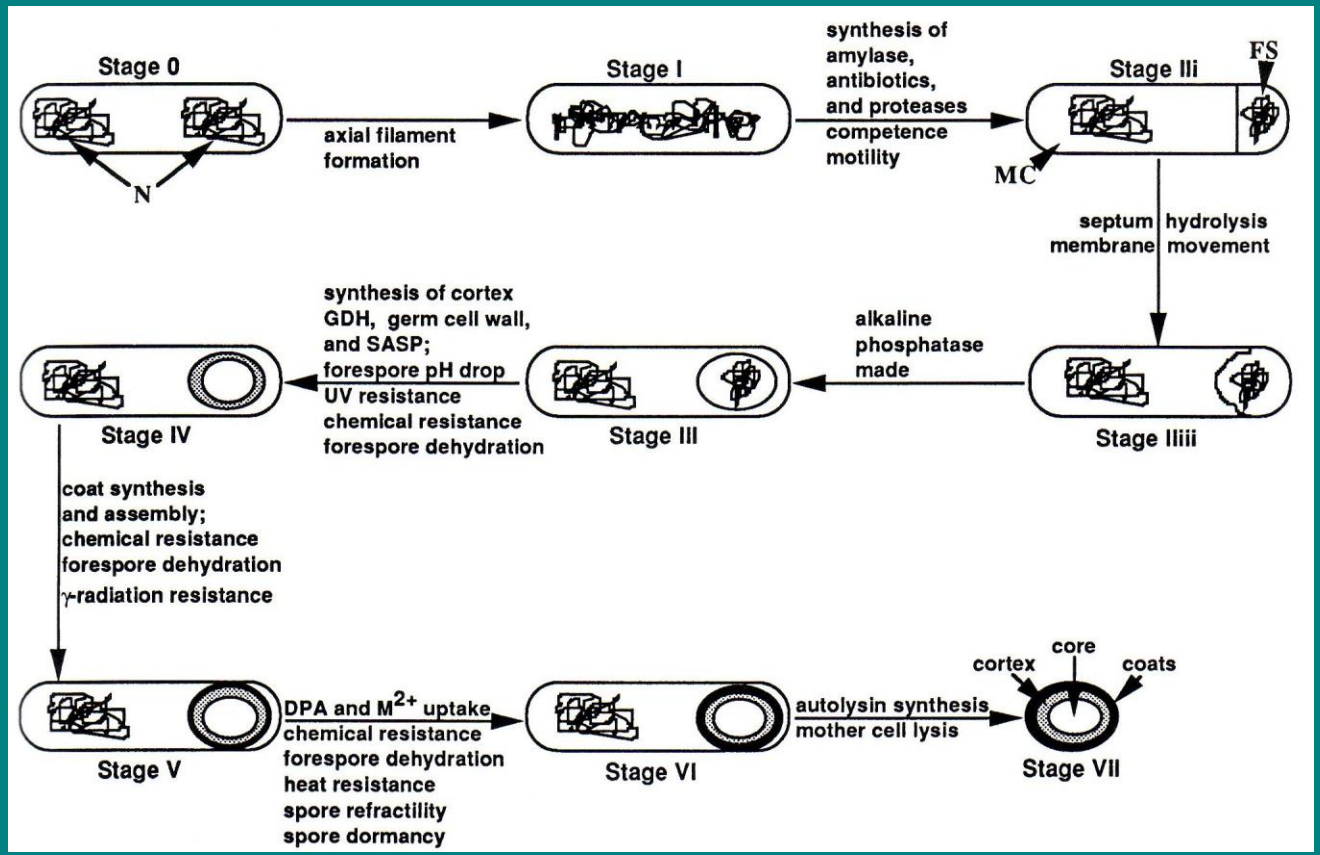


Spores

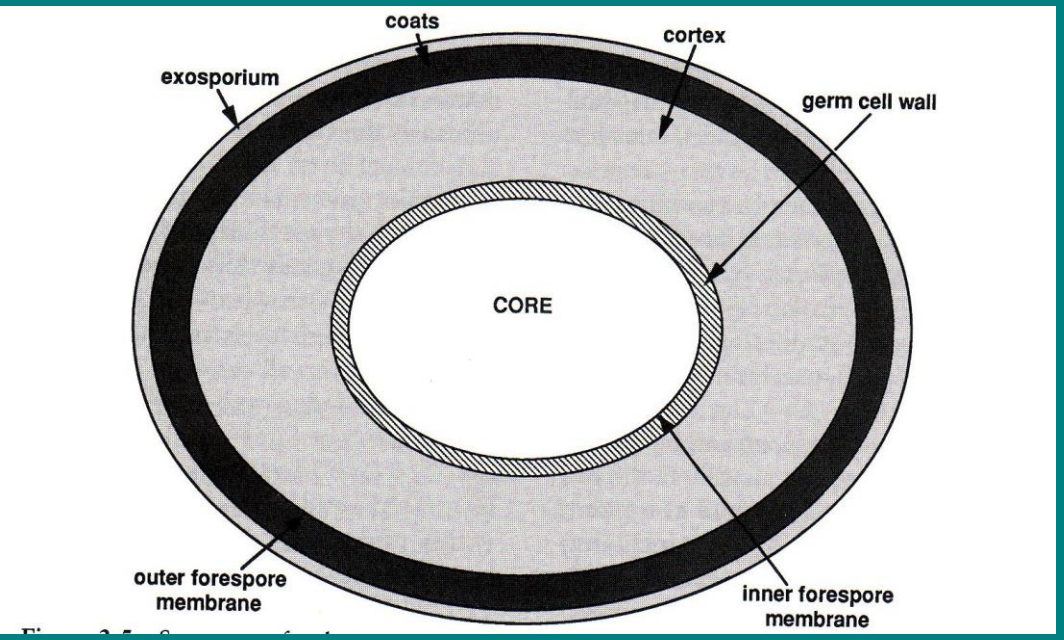
- Metabolically dormant
- Offer resistance to:
  - Low nutrients
  - Freezing
  - Heat
  - Dessication
  - Pressure
  - Radiation (gamma and UV)
  - Chemicals

Spores

- Sporulation
  - Nutrient limitation
  - Environmental stress
  - Percentage of spores increase as growth rate decreases



Spores



- Exosporium-??
- Spore Coat- protects cortex from lytic enzymes
- Cortex-similar to cell wall peptidoglycan (amino acid differences)
- Germ Cell Wall- identical to vegetative cell
- Forespore membranes- permeability barrier to hydrophilic compounds
- Core- DNA, RNA, ribosomes, enzymes, DPA, cations

Spores

- Activation, Germination, and Outgrowth

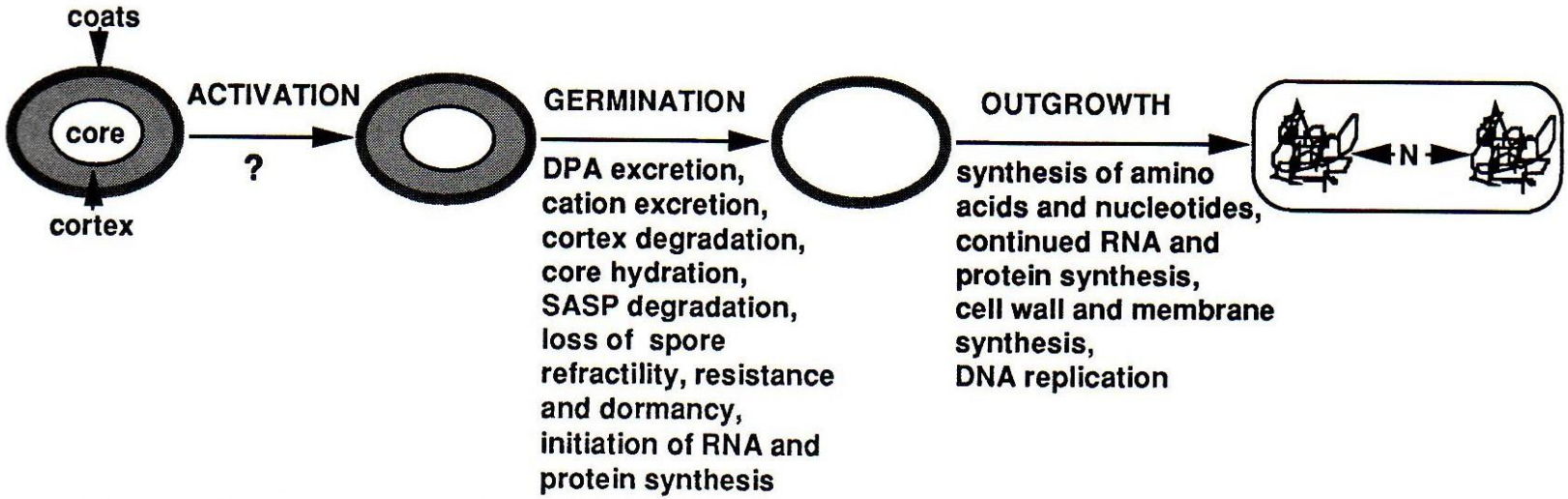


Figure 3.9 Spore activation, germination, and outgrowth. The events in activation are not known, hence the question mark. The loss of the spore cortex and the hydration and swelling of the core are shown in the germinated spore. Data are taken from references 70 and 207.

Viruses in Food

- Many of same factors control persistence/survival
- No growth
- Source typically fecal contamination
  - Food-handler
  - Waterwashed
  - Shellfish

DALLAS

Man Convicted of Sprinkling Fecal Matter on Pastries

Oct 27, 2005, 03:36 AM

A Dallas man will likely be sentenced today, one day after a jury convicted him of sprinkling feces on pastries at a grocery store.

Prosecutors charged 49-year-old Behrouz Nahidmobarekeh with two felony counts of tampering with consumer products.

During the trial, the jury saw store surveillance videotapes of the man tainting the food.

Customers had complained the fresh-baked items smelled and tasted like manure.

Nahidmobarekeh could get anywhere from 10 years probation to two to 20 years in prison.

Keeping food safe during severe weather emergencies
October 25, 2005
FSIS News Release
http://www.fsis.usda.gov/News_&_Events/NR_102505_01/index.asp

Dole sued for outbreak
October 26, 2005
Monterey Herald (California)
Dania Akkad
http://www.montereyherald.com/mld/montereyherald/business/13000076.htm

E coli outbreak in Bend

Bend.com news sources
Posted: Monday, October 24, 2005 9:38 AM

Deschutes County Public Health, Deschutes County Environmental Health, and the Oregon Department of Human Services are investigating an outbreak of E. coli O157:H7 infection with common exposure at McGrath's Fish House in Bend.

March 23 2007

- **E. coli outbreak linked to California spinach field**
  - **Contamination could have come from tainted water, cow feces, or wild pigs at the field, a report shows**

March 29, 2007

- **Outbreak of severe gastroenteritis with multiple aetiologies caused by contaminated drinking water in Denmark, January 2007**

October 19, 2007

- **Salmonella Pot Pies hit Washington State**

October 22, 2007

- **Topps E. coli Outbreak Spreads to Connecticut (2), Florida (1), Indiana (1), Maine (1), New Jersey (9), New York (13), Ohio (1), and Pennsylvania (12) - 40 sickened**
  Posted on October 20, 2007 by Botulism Attorney

  Source of Article: http://www.marlerblog.com/

Food Recall

- 2009 PCA Peanut Recall
  - 2,100 products in 17 categories by more than 200 companies
- Hamburger Recalls
  - 41,412,504 pounds since 2007
  - Not counting 2008 recall of 143,383,823 pounds of raw and frozen beef products