Types of Mobility in Porous Media

- Active Transport
  - Some bugs are motile
- Advective transport
- Diffusive/Dispersive Transport
  - Brownian Motion
  - Mechanical Dispersion

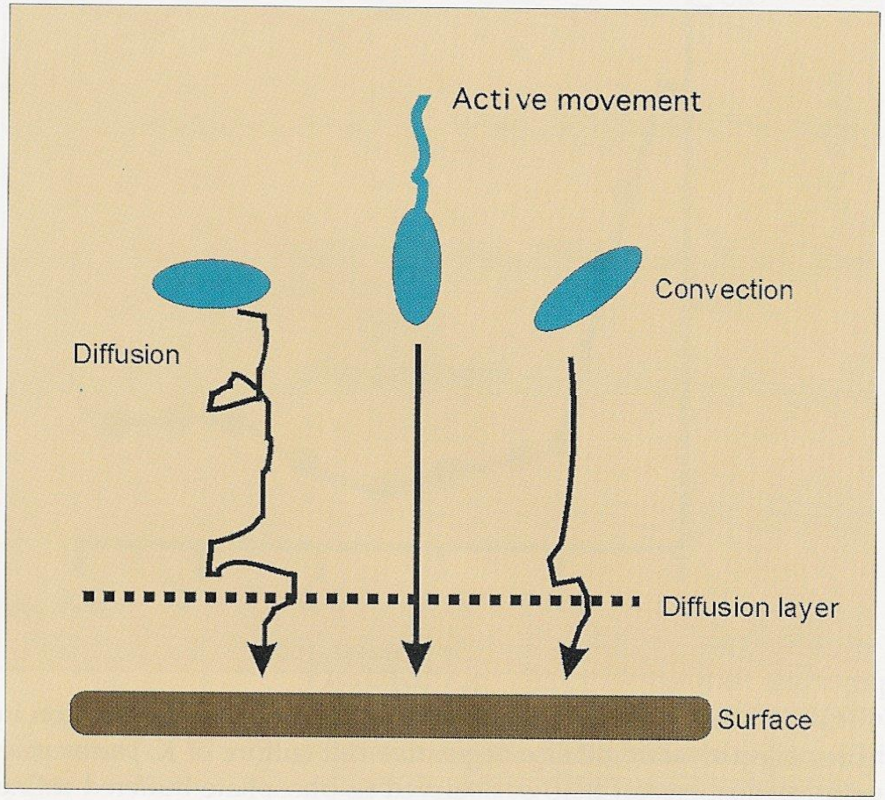


FIGURE 7.5 Different ways in which a cell can approach a solid surface. (Modified with permission from van Loosdrecht *et al.*, 1990.)

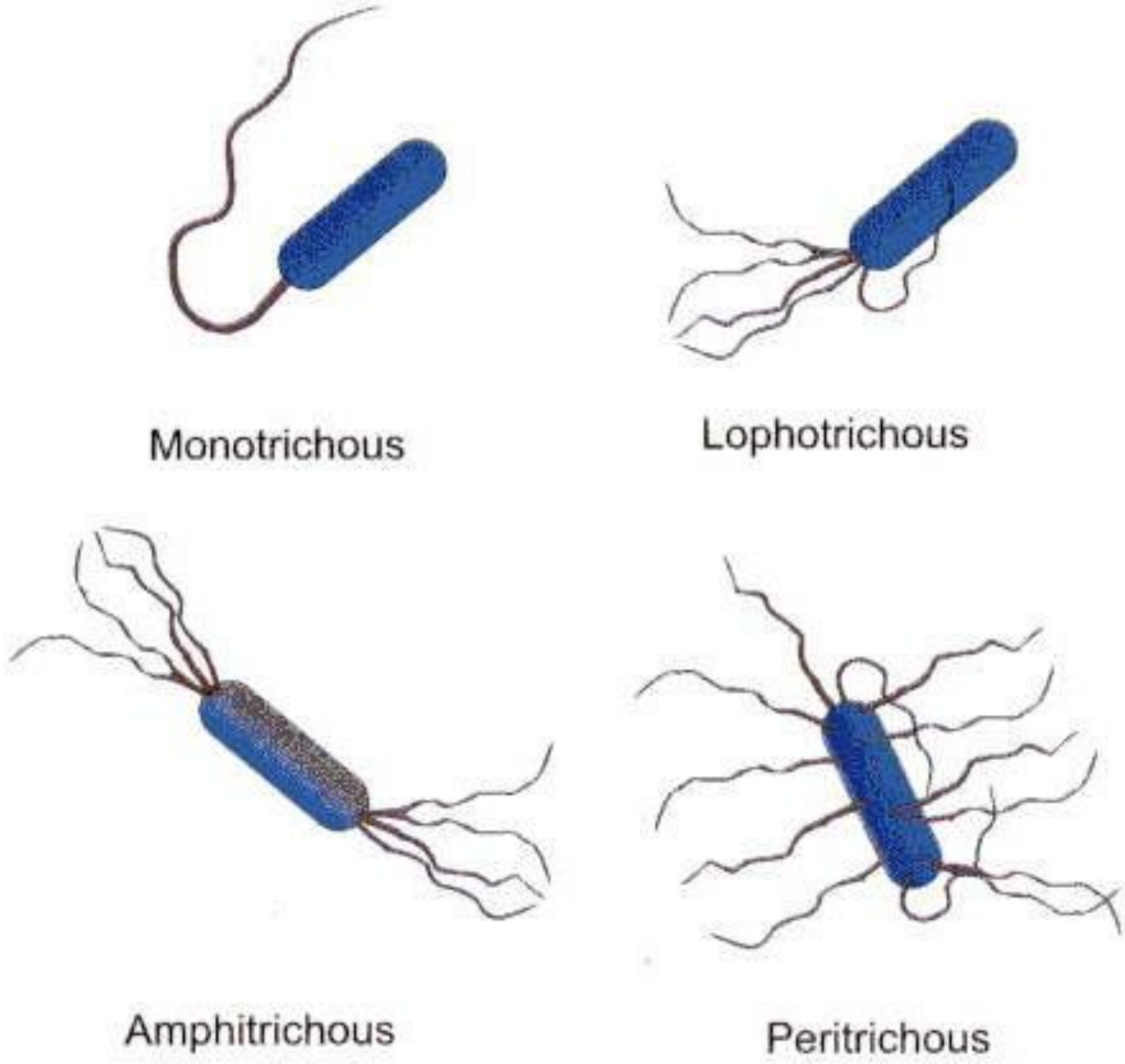


FIGURE 2.10 Arrangement of flagella extending from the cell envelope.

Extrinsic Factors Influencing Microbial Transport Through Soil

- **Soil texture:** Transport through sand > silt >clay
- **Size of microbe:** smaller microbes penetrate soils better
  - **Transport of virus > bacteria > protozoa**
- **Soil moisture:**
  - transport for saturated soil > unsaturated soils
- **Surface charge on microbes: generally negative**
  - less sorption to negatively charged colloids
  - More sorption to positively charged colloids
- **pH:** in relation to microbe isoelectric point and charge
- **Hydrophobicity:** influences sorption and transport
- **Organic matter:**
  - often decreases adsorption
  - competitive binding to adsorption sites on soils
  - Microbial activity and biofilms
- **Hydrogeological Factors:**

Adsorption/Adhesion

- May be reversible or non-reversible
- 3 main forces
  - Electrostatic
  - Hydrophobic
  - Van der Waals forces

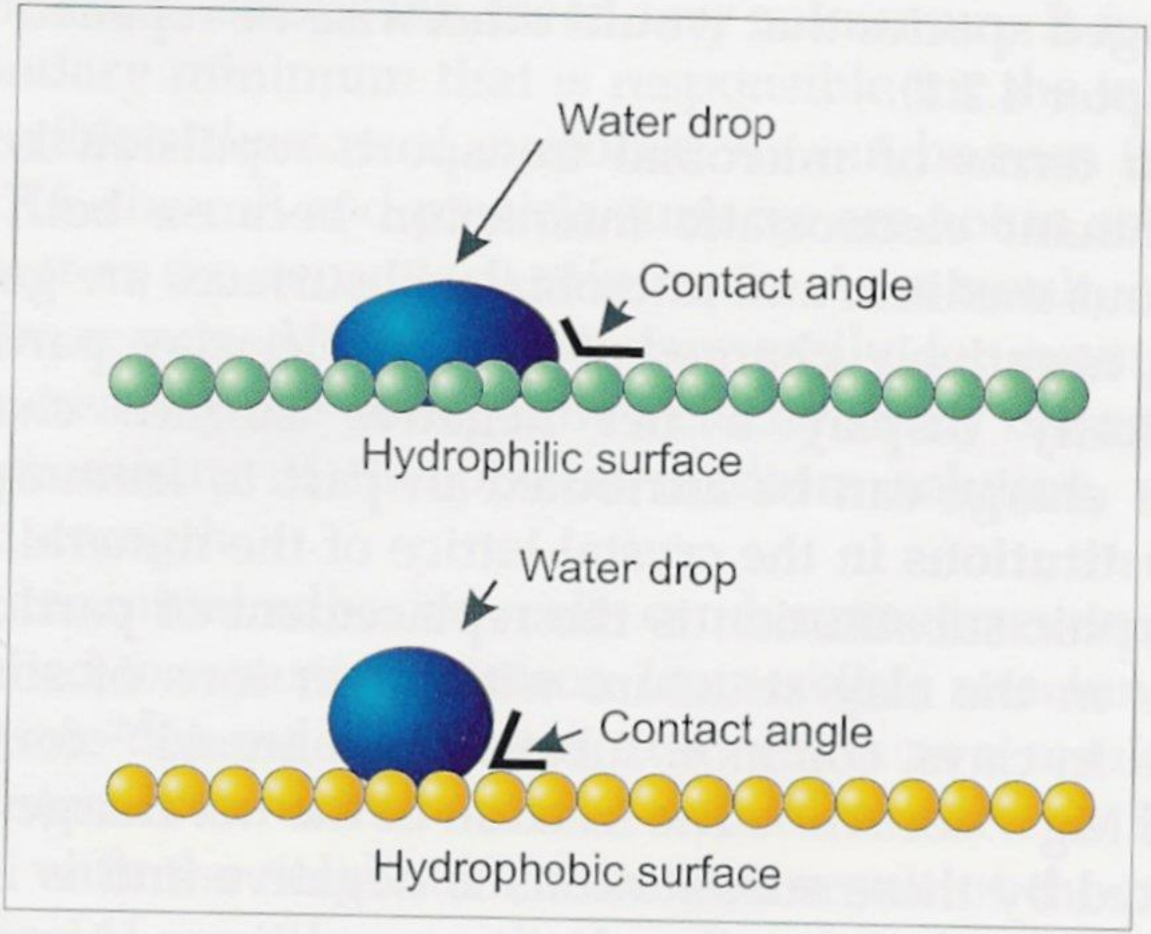
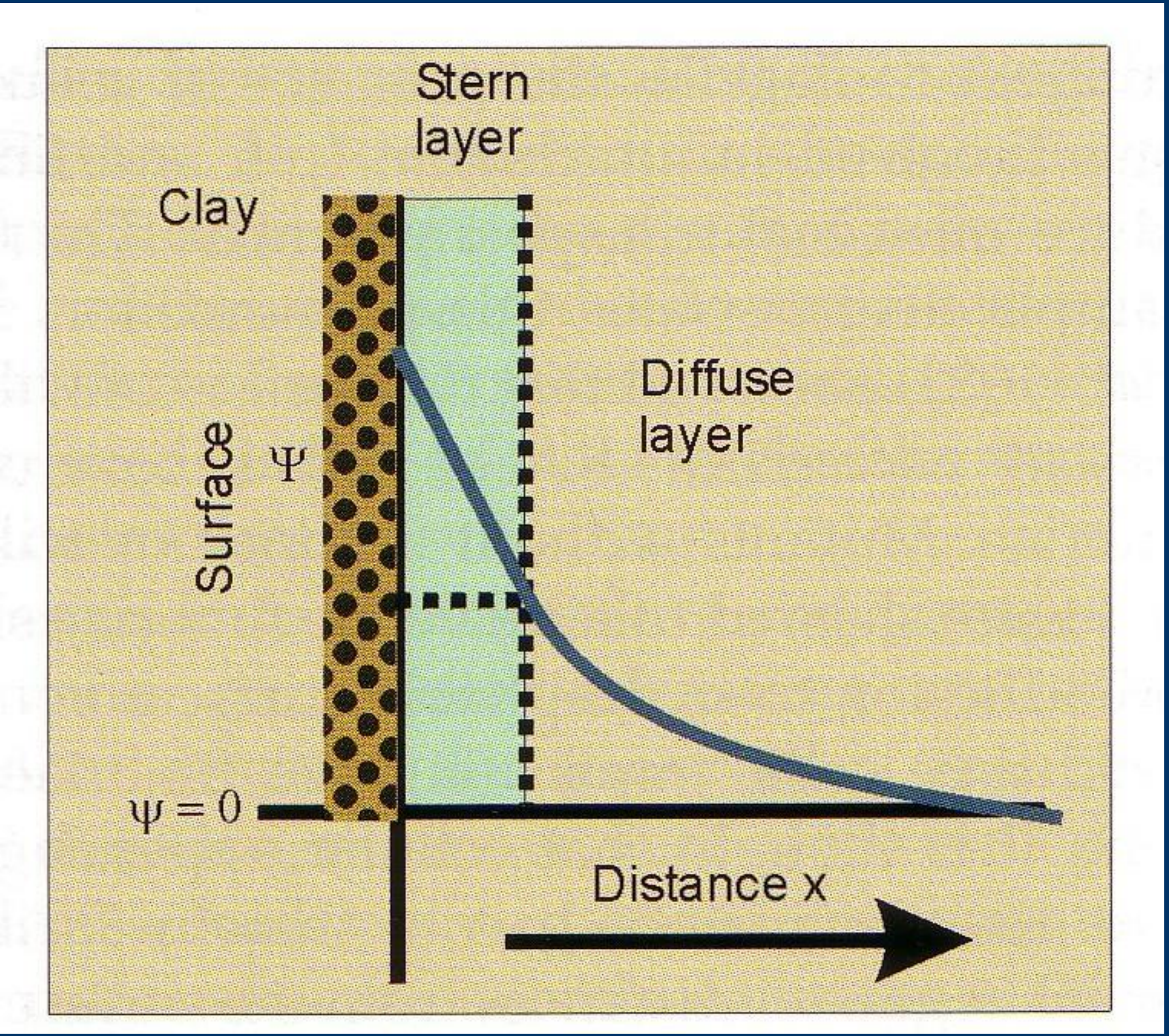


FIGURE 7.9 Water, which is a polar material, spreads out on a hydrophilic or polar surface but forms a round bead on a hydrophobic or nonpolar surface. The angle that describes the interaction of a water droplet with a surface is called the contact angle.

DDL Theory of Colloidal Attachment



IEP (pI)

Electrophoretic Mobility

Stern Layer

Gouy Layer

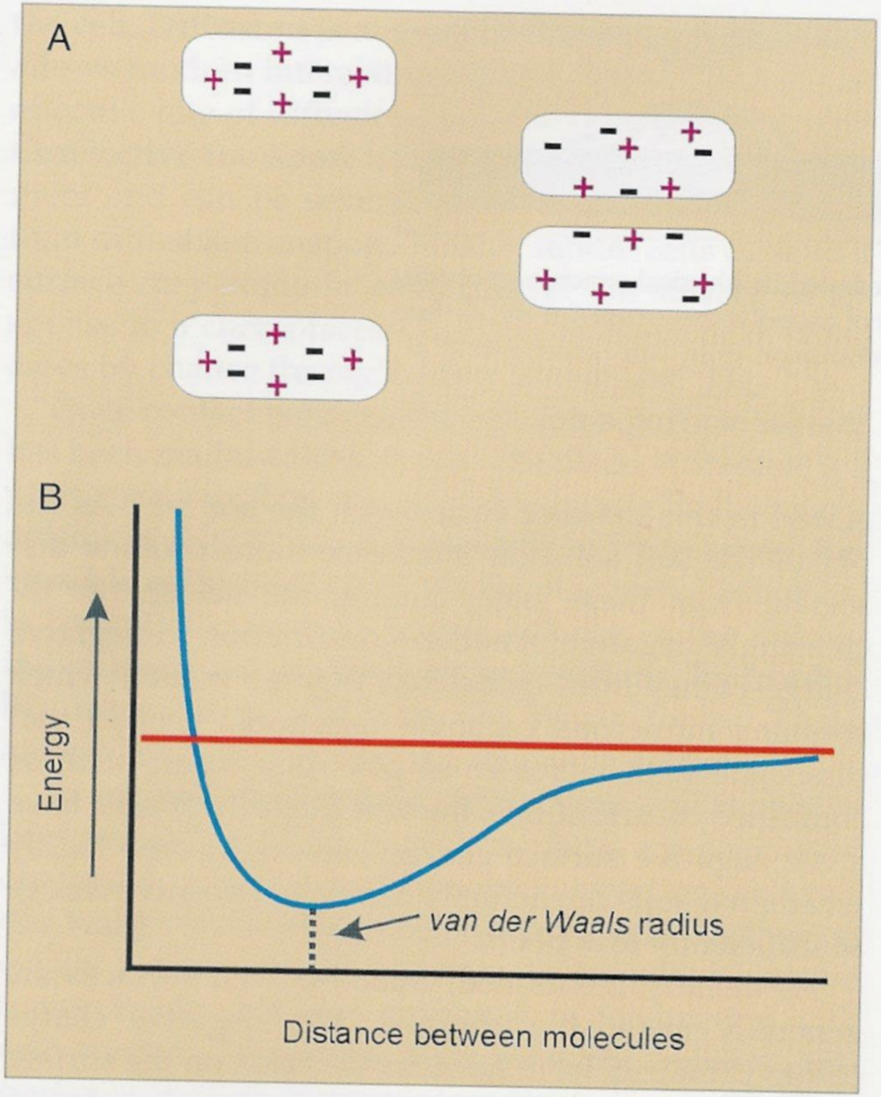


FIGURE 7.8 (A) For a neutral molecule the charge distribution in a molecule can vary to produce a net electrostatic attraction, allowing the molecules to approach very closely. This is a very weak attraction called the van der Waals force. Van der Waals forces can become strong if they are numerous enough. (B) As two molecules approach each other, the van der Waals attractive force increases to a maximum, then decreases and becomes repulsive.

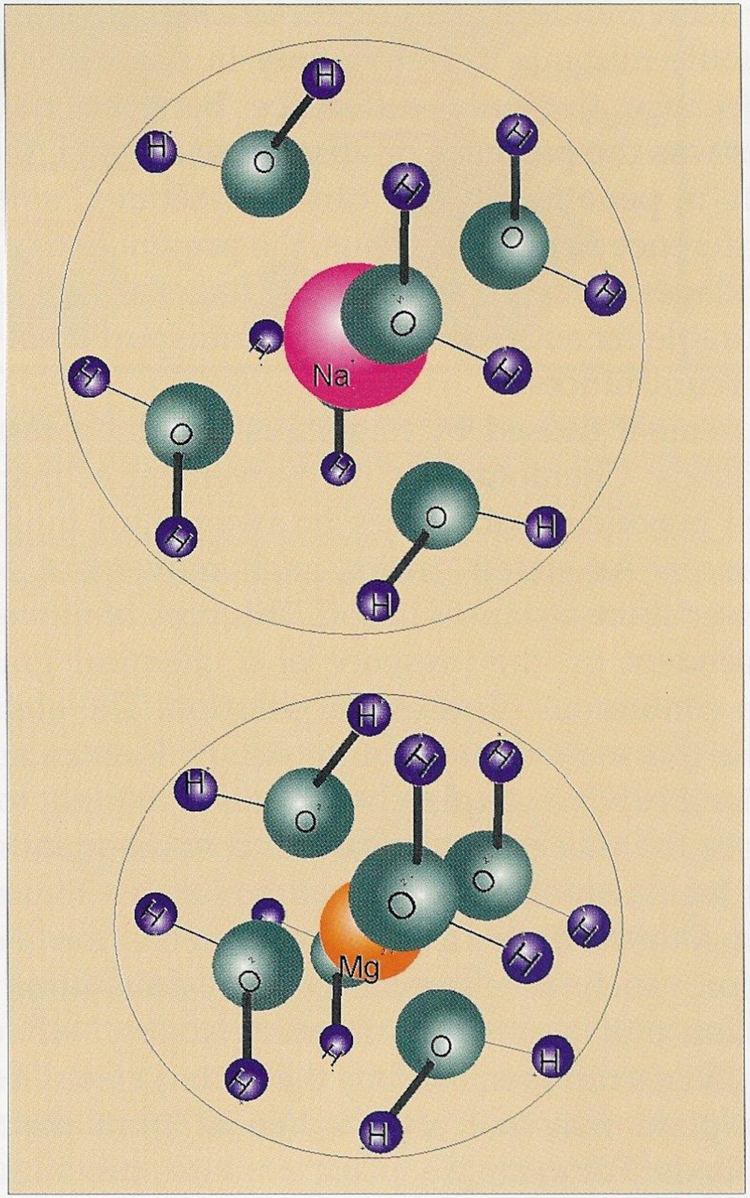
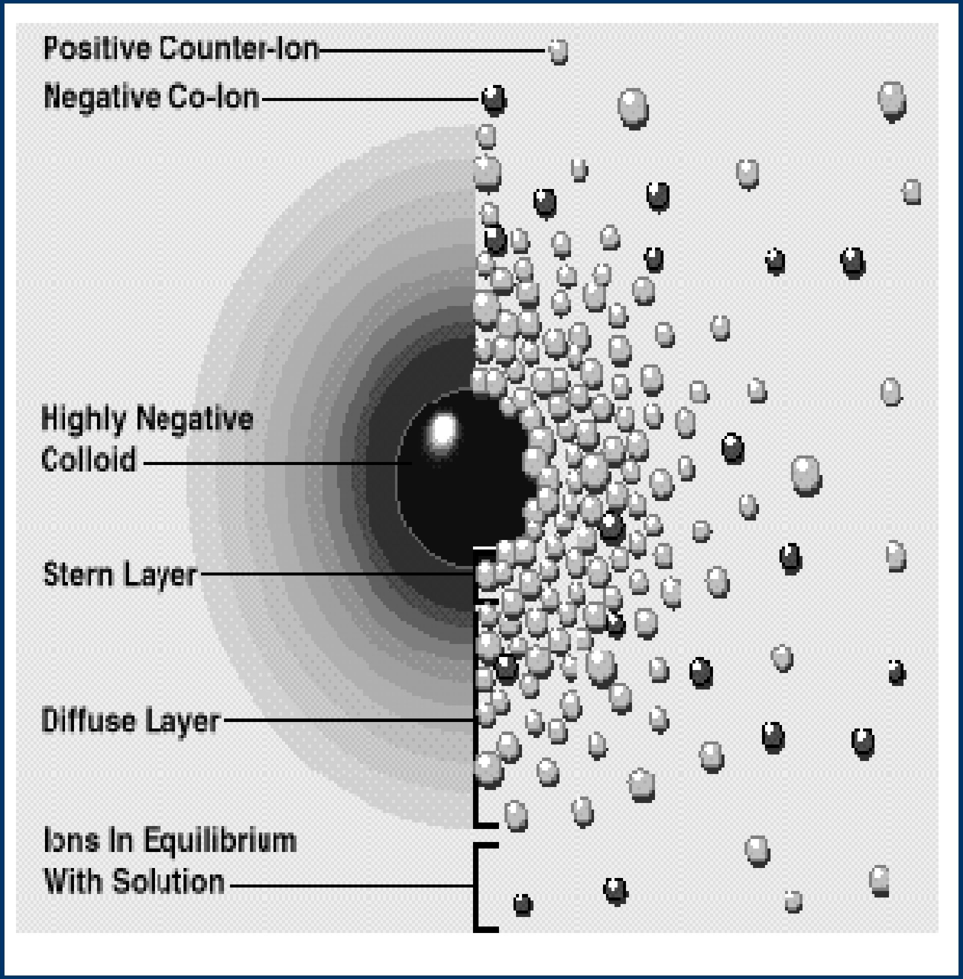
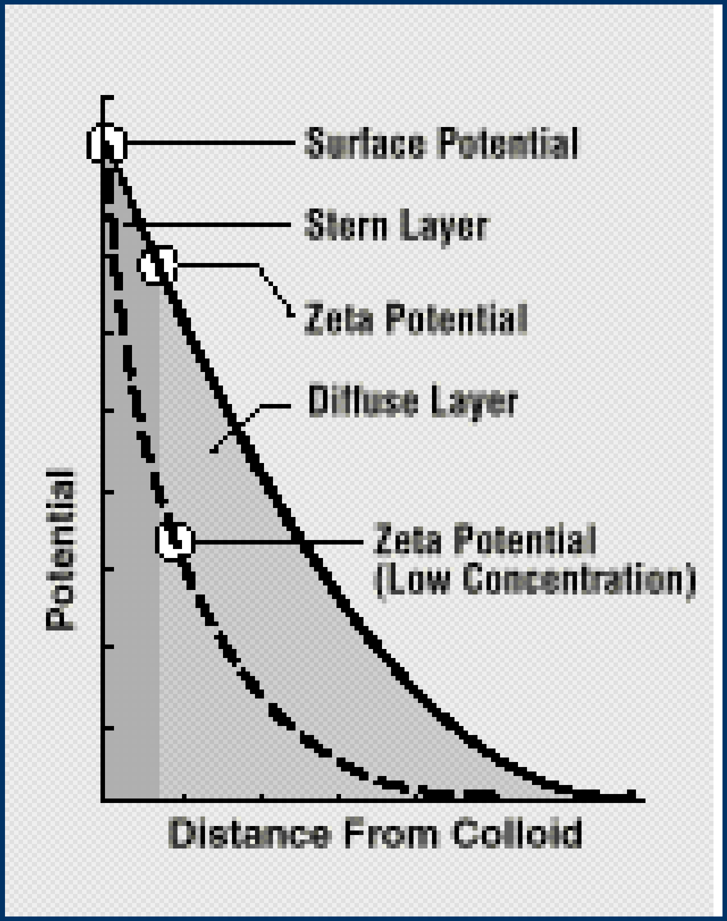


FIGURE 7.12 The radius of hydration of a cation in soil depends on the charge density of the atom. In the example shown, magnesium has a higher charge density than sodium and thus attracts water molecules more strongly resulting in a larger radius of hydration.

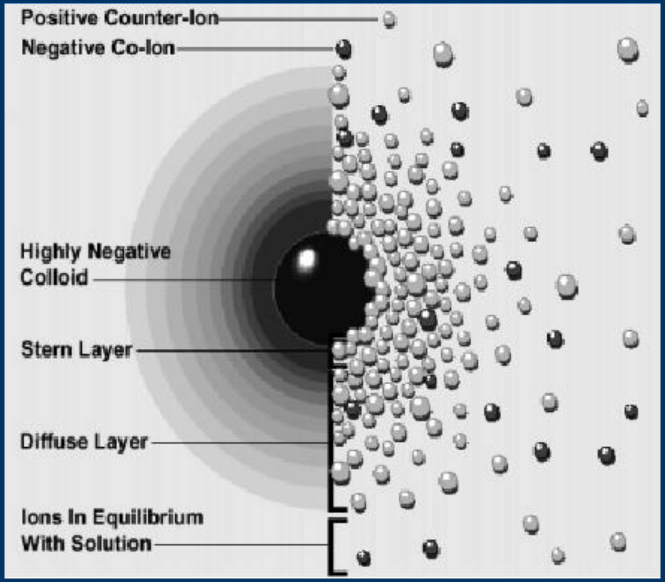
Diagram of Colloid Particle and Its Surface Electrical Potentials





Colloidal Particles and their Charge Properties

- Colloids: small charged, suspended particles
  - Abiotic and biotic particles
  - Most microbes are colloids
- Particle surface has its own charge and a strongly bound layer of opposite charged counterions, called the Stern layer
- Positive ions are still attracted by a negative colloid and vice-versa
- Stern layer: the layer of the actual particle and its immediately bound counter ions.
- Beyond the Stern layer is a diffuse layer of ions that moves with the particle when it is in motion
- Zeta potential : the potential at the shear plane; the layer of bound ions that moves with the particle



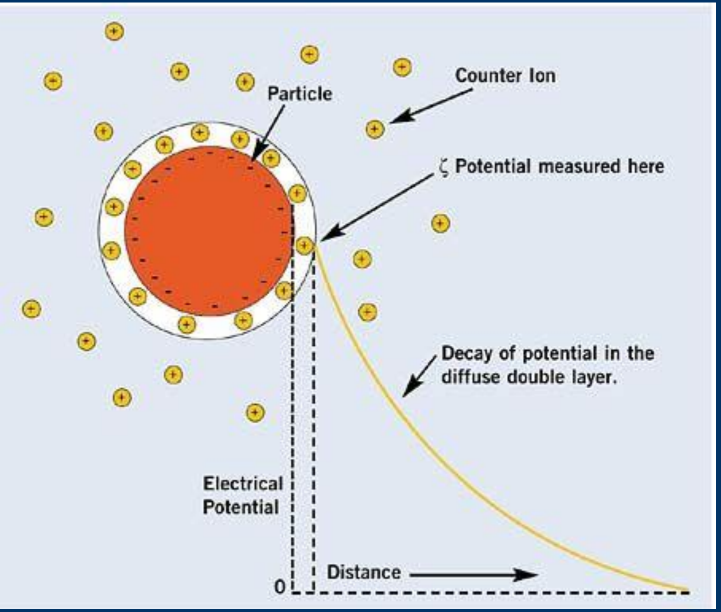


Table 4–1. L-α-Amino acids present in proteins.*

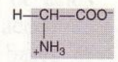
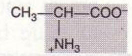
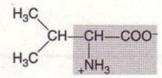
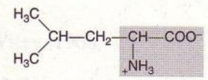
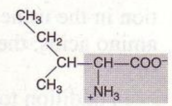
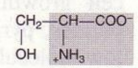
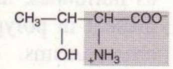
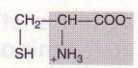
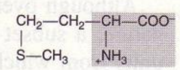
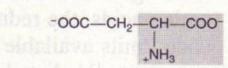
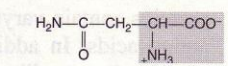
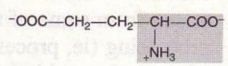
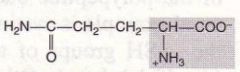
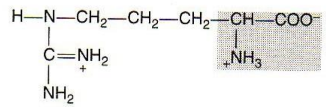
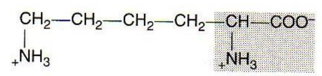
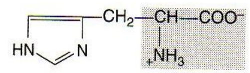
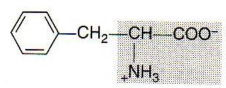
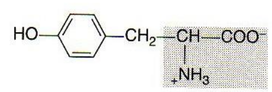
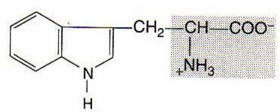
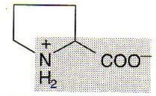
Name	Symbol	Structural Formula	pK1	pK2	pK3
			α-COOH	α-NH_3^+	R Group
With Aliphatic Side Chains					
Glycine	Gly [G]		2.4	9.8	
Alanine	Ala [A]		2.4	9.9	
Valine	Val [V]		2.2	9.7	
Leucine	Leu [L]		2.3	9.7	
Isoleucine	Ile [I]		2.3	9.8	
With Side Chains Containing Hydroxylic (OH) Groups					
Serine	Ser [S]		2.2	9.2	about 13
Threonine	Thr [T]		2.1	9.1	about 13
Tyrosine	Tyr [Y]	See below.			
With Side Chains Containing Sulfur Atoms					
Cysteine	Cys [C]		1.9	10.8	8.3
Methionine	Met [M]		2.1	9.3	
With Side Chains Containing Acidic Groups or Their Amides					
Aspartic acid	Asp [D]		2.0	9.9	3.9
Asparagine	Asn [N]		2.1	8.8	
Glutamic acid	Glu [E]		2.1	9.5	4.1
Glutamine	Gln [Q]		2.2	9.1	

Table 4–1. L-α-Amino acids present in proteins.* (continued)

Name	Symbol	Structural Formula	pK_1 α-COOH	pK_2 α-NH_3^+	pK_3 R Group
With Side Chains Containing Basic Groups					
Arginine	Arg [R]		1.8	9.0	12.5
Lysine	Lys [K]		2.2	9.2	10.8
Histidine	His [H]		1.8	9.3	6.0
Containing Aromatic Rings					
Histidine	His [H]	See above.			
Phenylalanine	Phe [F]		2.2	9.2	
Tyrosine	Tyr [Y]		2.2	9.1	10.1
Tryptophan	Trp [W]		2.4	9.4	
Imino Acids					
Proline	Pro [P]		2.0	10.6	

Electrophoretic mobility of rNV particles (circles) and MS2 (squares) as a function of solution pH in the presence of 0.01 M NaCl.

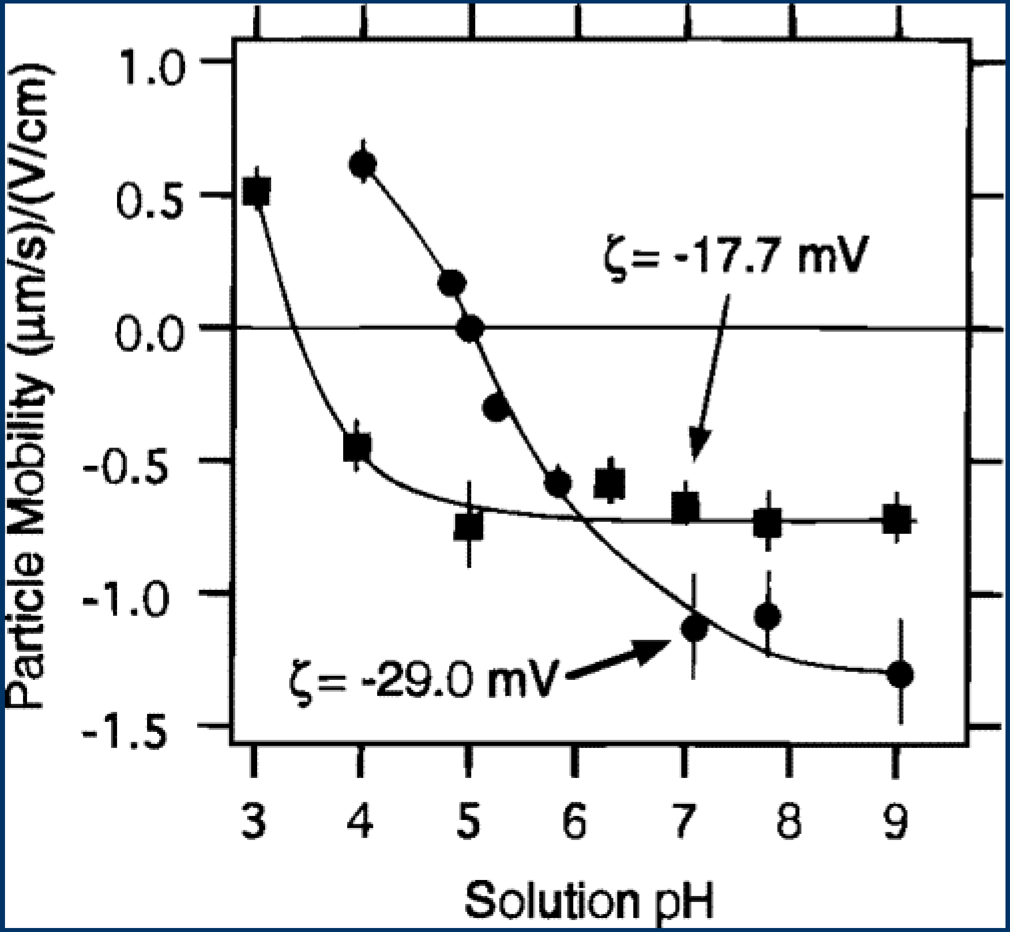


Table 4–2. Classification of the L-α-amino acids of proteins based on their relative hydrophilicity (tendency to associate with water) or hydrophobicity (tendency to avoid water in favor of a more nonpolar environment).

Hydrophobic	Hydrophilic	
Alanine	Arginine	Histidine
Isoleucine	Asparagine	Lysine
Leucine	Aspartic acid	Serine
Methionine	Cysteine	Threonine
Phenylalanine	Glutamic acid	
Proline	Glutamine	
Tryptophan	Glycine	
Tyrosine		
Valine		

Advective transport

- Transport by the flow of groundwater
- Governed hydraulic head
- Generally considered to be laminar

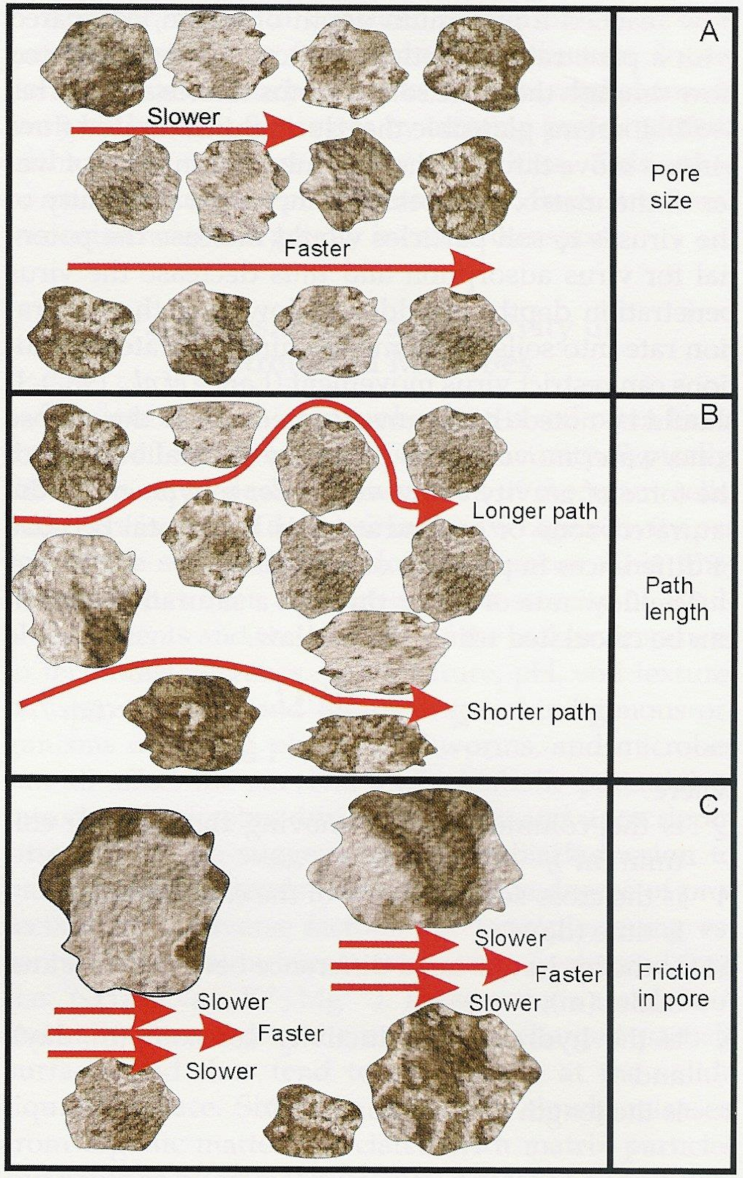


FIGURE 7.14 Factors causing mechanical dispersion at the scale of individual pores. A) microbes are transported through small pores more slowly than through large pores; B) depending on pore sizes and shapes, path lengths can vary considerably; C) flow rates are slower near the edges of the pore than in the middle. (Modified with permission from Fetter, 1993, © MacMillan Magazines Limited.)

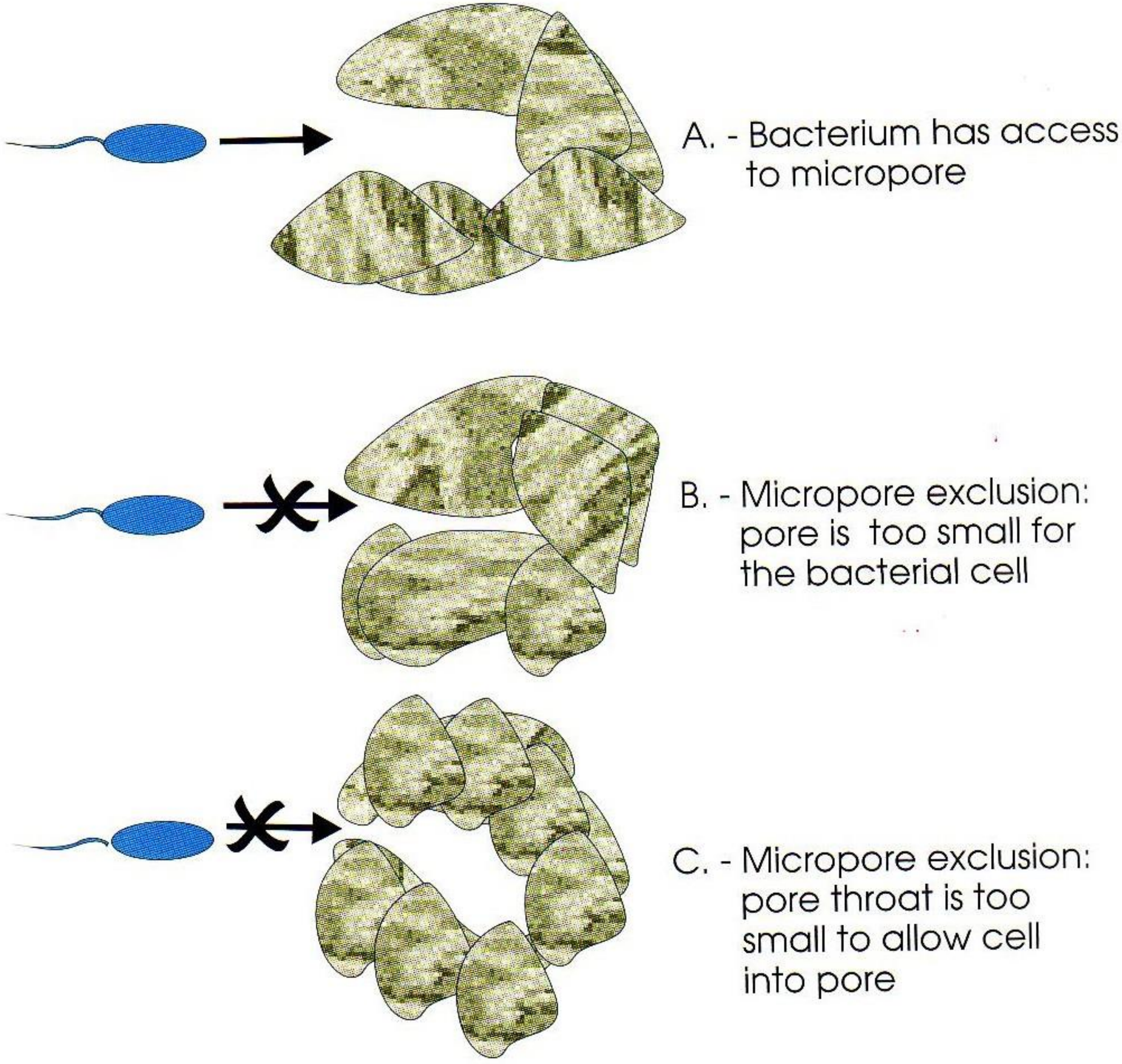
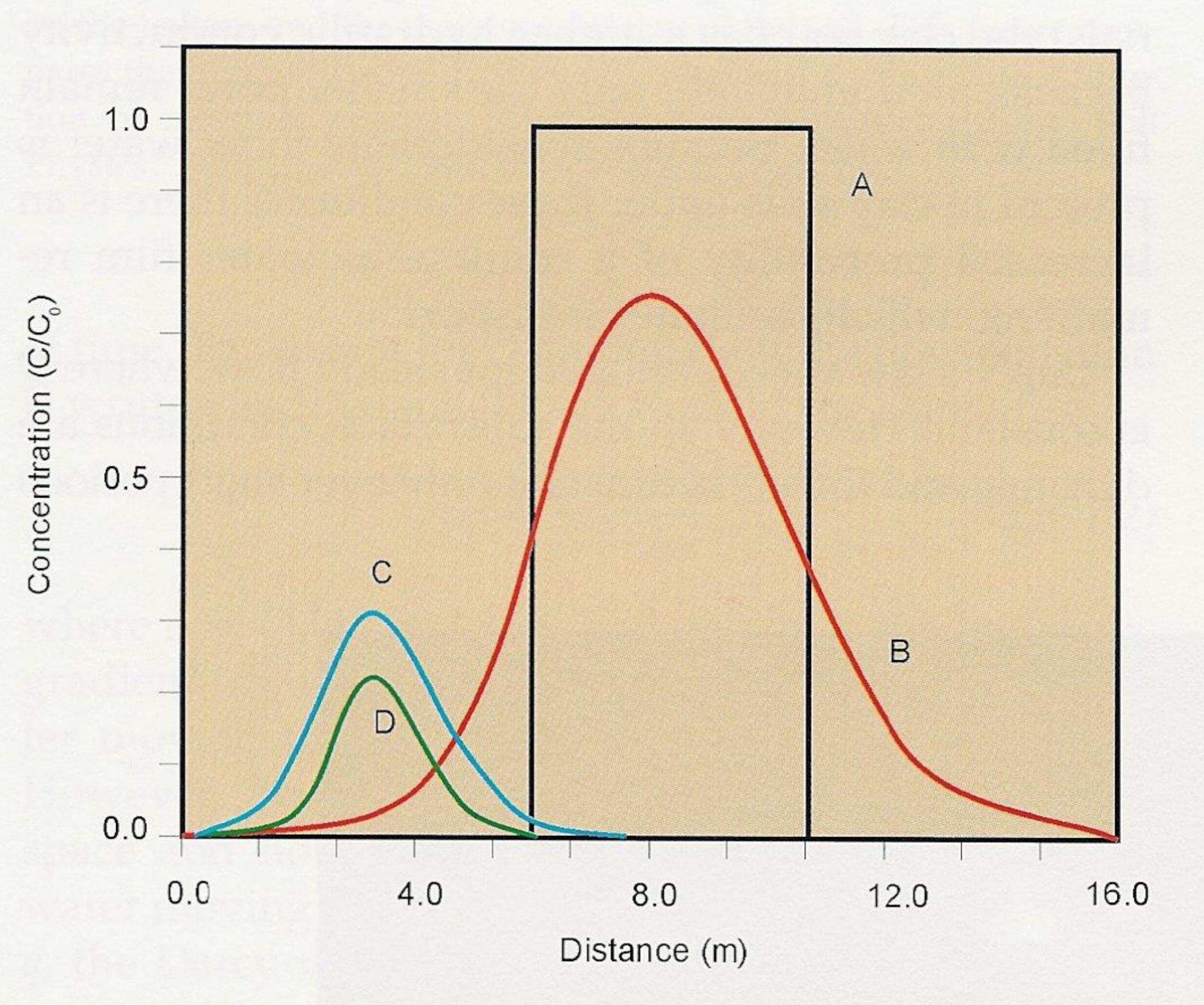


FIGURE 7.1 Exclusion of a bacterial cell from microporous domains in structured porous media.



Concentration (C/C_0)
1.0
0.5
0.0
A
B
C
D
0.0
4.0
8.0
12.0
16.0
Distance (m)

Microbes on Surfaces: *Fomitic Transmission*

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Myths

- STDS can be caught from Toilet seats
  - False: likely to catch diarrhea not gonorrhea
- Ammonia and vinegar kill germs
  - False: work on dirt, but not bacteria or viruses
- Telephones and doorknobs spread viruses
  - Maybe: not enough research for good conclusion; staph ear infections have been shown in teenagers
- Plastic cutting boards are better than wood; or vice versa
  - False: Actually a toss up, either should be disinfected after use

USEPA Default Exposure Factors

• Water	~2L/day
• Soil/Dust	200mg/day (child <6) 100mg/day (adult)
• Air	15-20 m^3/day 600 L/hr

USEPA, 1997

Shedding and Infectious Dose

Organism	Shedding Rate (per gram)	Infectious Dose
HAV	10^6	<100
Norovirus	10^5-10^9	10-100
Rotavirus	10^6-10^{10}	<100
Salmonella	10^4-10^{11}	10^4-10^6
Shigella	10^5-10^9	10^2-10^4
Giardia	10^5	~100

Surface Transmission

- Mechanical Vector
  - E.g. hands
- Fomites
  - Inanimate surfaces
- Food??

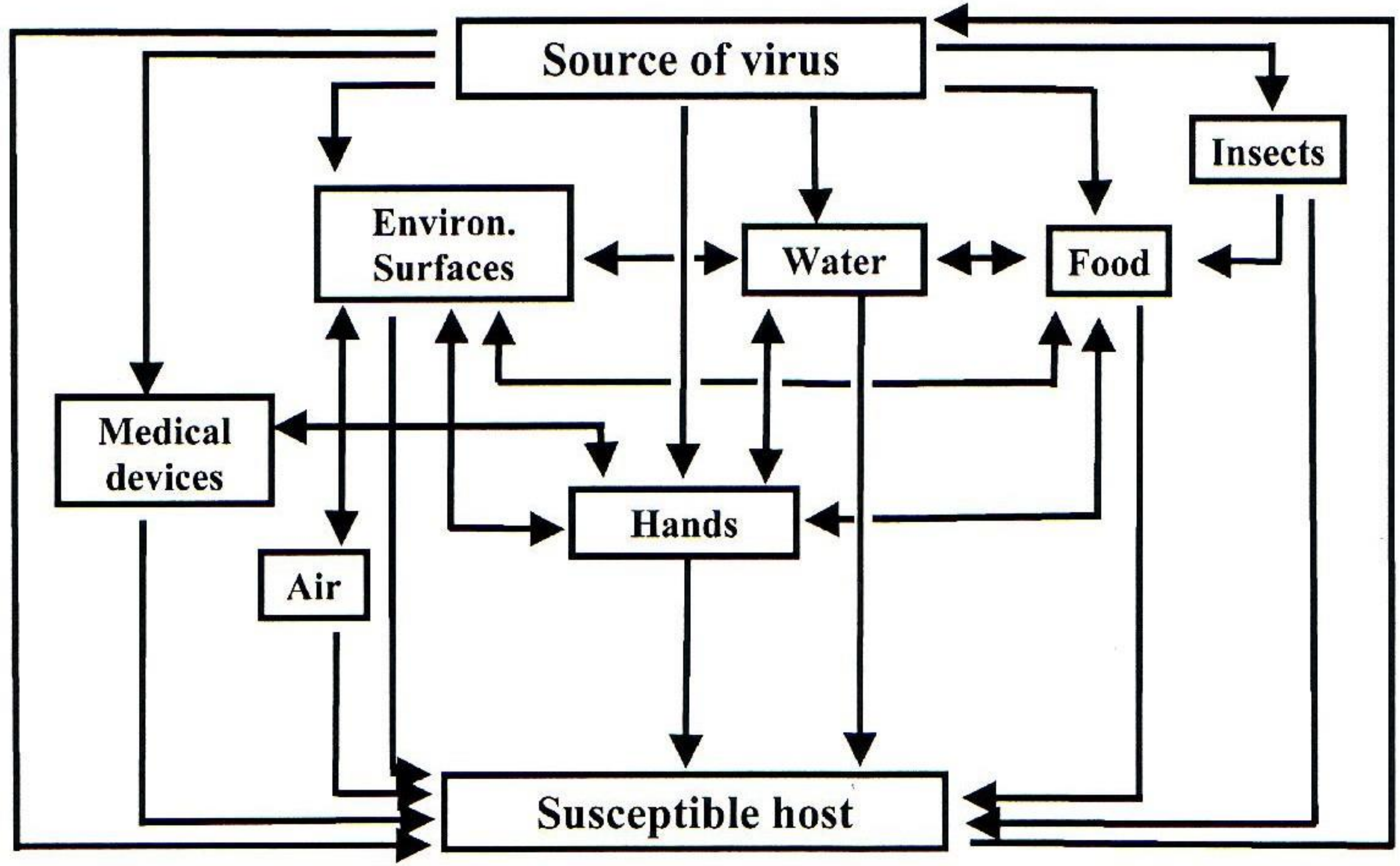


Figure 1 Direct and indirect vehicular spread of nosocomial viral infections.

What surfaces can transmit pathogens?

Pathogen Survival on Surfaces

- What does it mean?
- What are the important things to know in order to understand it?
- Why is it important?

e.g. Virus Survival on Surfaces

- Non-Enveloped Viruses
  - Poliovirus has been shown to survive for up to 20 weeks on wool blanket fabric (Dixon, 1966)
  - HAV has been recovered from stainless steel surfaces after 96 hours; and from plastic surfaces after 1 month (Mbithi, 1991)
  - Rotavirus may persist for up to 10 days (Sattar, 1986)
- Enveloped Viruses
  - Influenza may persist for several days to weeks on dust, cotton sheets, and glass slides (Edward, 1941); 24-48 hours on other hard surfaces (Bean et al, 1982)
  - RSV was reduced by 2 $\log_{10}$ after 24 hours (Kingston, 1968)
  - Parainfluenza virus may persist up to 12 days on plastic surfaces (Parkinson, 1983)
  - Human Coronavirus has been shown to persist up to 6 hours with 1-2 $\log_{10}$ reduction

Surface Sampling

- Current Methods (5-90% recoveries, generally poorly characterized)
  - Swabs (better for gram negatives?)
    - Cotton
    - Dacron
    - Calcium Alginate (may inhibit PCR and be toxic to cell culture)
    - Sponge (Polyurethane and Cellulose)
  - Swipes/Wipes
    - Cotton
    - Nitrocellulose membranes
    - Polyester bonded cloth
    - Velvet or Velveteen
  - Vacuum Filtration
    - Hepa bag vac
    - Wet Vac
  - Rinse/Elute
  - Contact Plates and Paddles (RODAC) (better for gram positives?)
- New Methods
  - Adhesive Strips and Paddles
  - Scraping/Aspiration

Yamaguchi, et al. 2003; Cloud, et al. 2002; Lemmen, et al, 2001; Poletti, 1999; Craythorn, et al. 1980; Osterblad, et al. 2003; Taku, et al. 2003

Recovery from Surfaces

- Factors that may affect the recovery of microbes from surfaces:
  - Method selection
    - Particle size bias
  - Surface composition
  - Surface topography/roughness
  - Organism type and Distribution
  - Sample size
  - Target of detection method to be utilized

Sanderson et al –Methods

- Survey 1 –surface wipe, HEPA vacuum, air filters
- Survey 2 –surfaces swabs incorporated
  - Reported separately

Surface Sampling

From anthrax investigations, methods performed in parallel

- Dry Swabs (<25%)
- Wet Swabs (~50%)
- Hepa Vac (~80%)
- Wipe (~85%)

Teshale, et al. 2002; Sanderson, et al. 2002.

Table 1 Results of sampling for *Bacillus anthracis* spores by sample type within survey

	Method	No. of samples tested	*B. anthracis* detected *n* (%)	Median* (CFU/sample)	Range* (CFU/sample)	Level† Neg.	Low	Med.	High
First survey 23–28 October 2001	Wipe	114	8 (7)	ND	ND	106	ND	ND	ND
	HEPA vacuum	39	27 (69)	11 400	$3–13·3 \times 10^6$	12	5	6	16
	Air	12	0	–	–	12	0	0	0
Second survey 17–20 December 2001	Wet swab	67	36 (54)	3	1 to >300	31	26	1	9
	Wipe	67	58 (87)	200	1 to >300	9	20	10	28
	HEPA vacuum	59	49 (83)	25 000	$80–49·6 \times 10^6$	10	1	4	44

*For positive samples only.

†Level of *B. anthracis* (CFU): negative = 0, low = 0–100, medium = 100–300 and high = >300.

ND = not determined.

Table 2 Results of sampling for *Bacillus anthracis* spores by location within postal facility samples collected during both investigations (23–28 October and 17–20 December 2001)

Location	Wet swab samples *N* (% Pos)	Median (CFU)	Maximum (CFU)	Wet wipe samples *N* (% Pos)	Median (CFU)	Maximum (CFU)	HEPA vacuum sock samples *N* (% Pos)	Median (CFU)	Maximum (CFU)
DBCS machine 17	13 (93)	>300	>300	19 (100)	>300	>300	8 (100)	468 000	$49·6 \times 10^6$
Other DBCS machines	10 (20)	3	3	54 (22)	15	200	14 (64)	352	$1·39 \times 10^6$
Within 15 m of DBCS machine 17	NS	–	–	9 (11)	–	–	3 (100)	22 400	$4·82 \times 10^6$
Secure area – 23 m from DBCS machine 17	18 (72)	4	250	18 (94)	300	>300	18 (100)	22 600	102 000
Loading dock and vehicle transportation office	NS	–	–	11 (0)	–	–	4 (50)	194	348
Express mail room	NS	–	–	3 (0)	–	–	2 (50)	–	200
Government mail area	1 (0)	–	–	17 (6)	–	100	9 (100)	17 900	13×10^6
Other locations in mail processing area	3 (0)	–	–	20 (0)	–	–	15 (67)	550	19 600
Administration and customer service area	NS	–	–	10 (0)	–	–	5 (0)	–	–

N, number of samples collected; CFU, colony forming units per sample; NS, not sampled.

Table 3 Results of sampling for *Bacillus anthracis* spores on inspector walkway portals samples collected during second investigation (17–20 December 2001)

Location		Samples (n)	Positive (n)	TNTC (n)	Median (CFU in^{-2})	Range (CFU in^{-2})
Directly above DBCS machine 17	Wet swab	3	3	0	58	29–233
	Wipe	3	3	3	18	18
	HEPA vacuum	3	3	NA	310	239–322
Within 30 m of DBCS machine 17	Wet swab	5	2	0	0	0–9
	Wipe	5	5	2	16	1–233
	HEPA vacuum	5	5	NA	67	6–264
Within 30–60 m of DBCS machine 17	Wet swab	8	6	0	0	0–58
	Wipe	8	7	1	7	0–18
	HEPA vacuum	8	7	NA	10	0–60
>60 m from DBCS machine 17	Wet swab	4	0	0	0	NA
	Wipe	4	1	0	0	0–15
	HEPA vacuum	4	1	NA	0	0–2

TNTC, too numerous to count; NA, not applicable.

Teshale et al--Methods

- Nov 11 –Dry synthetic swabs by contractor
- Nov 21 –Dry swabs by 2nd contractor
- Nov 25 –Wet synthetic swabs investigation team
- Nov 28 –Wet synthetic wipes and HEPA vacuum samples
- Dec 2 –Additional wet wipe samples

Table 1. Number of samples taken from digital bar-code sorting machines during five sampling dates, Connecticut, 2001

Machine no.	11/11/01	11/21/01	11/25/01	11/28/01	12/02/01	Total samples
1			1	8		9
2			1	8		9
3				8		8
4				11[a]	48 [a]	59
5		2		12		14
6	1	2	3	23	48 [a]	77
7		2		12		14
8				8		8
9			1	8		9
10				8[b]	52[c]	60
11			1	8 [a]	52[d]	61
12				8		8
13			1	8		9
Total	1	6	8	130	200	345

[a]One positive sample.
[b]Four positive samples.
[c]Thirty positive samples.
[d]Three positive samples.

Table 2. Environmental sampling methods, types, and results of samples taken November 11–December 2, Southern Connecticut Processing and Distribution Center, 2001[a]

Sampling date	No. of samples	Samples from DBCS	Type	Positive results	Sample collectors
11/11/01	53	1	Dry swabs	0	USPS
11/21/01	64	6	Dry swabs	0	USPS
11/25/01	60	8	Wet swabs	0	CDC/ATSDR
11/28/01	212	131	Wet wipes and vacuum	6	CDC/ATSDR
12/02/01	200	200	Wet wipes	35	CDC/ATSDR
Total	589	346		41	

[a]DBCS, digital bar-code sorting; USPS, United States Postal Service; CDC, Centers for Disease Control and Prevention; ATSDR, Agency for Toxic Substances and Disease Registry.

Contamination of Clinic Surfaces with HPV

- Treatment rooms, toilets and cryoguns tested for accumulation of HPV after 1 day
- Decontamination day 1 with detergent and water (50% reduction in quantity, 73% reduction in type)
- Decontamination day 2 with detergent in alcohol

Table 1 Method of cleaning used and HPV DNA detection

	Sample 1, 16.30	Sample 2, 8.30	Sample 3, 16.30
	Detergent	Clearsol and methylated spirits	
Female treatment room			
Treatment/examination bed	11, 16	None	None
Light switch	6, 16	None	None
Examination lamp	None	None	None
Male treatment room			
Treatment/ examination bed	None	None	None
Light switch	16	None	6, 18
Examination lamp	None	None	None
Female toilet			
Light switch	None	None	None
Toilet flush handle	None	None	None
Toilet seat	None	None	None
Door handle	None	None	None
Cold tap	None	None	None
Hot tap	16	None	None
Male toilet			
Door handle	16	None	None
Hot tap	None	None	None
Cold tap	None	None	None
Light switch	None	None	None
Toilet seat	11, 16	None	None
Cryoguns			
1	6, 16, 58	Pos (6)	Pos (6, 11, 16, 18)
2	6	None	Pos (11)
3	16	None	Pos (6)

Microbes on Currency

- HSV
  - Little or no loss in 30 minutes
  - 2-3 log loss between 30-60 minutes
  - On penny some viable virus detected at 2 hours
- Fecal Bacteria (in Rangoon)
  - 0-10^7 cfu of TC or FC /sq cm
  - E.coli, Vibrio and Salmonella Pathogens isolated from money received from butchers and fish mongers.

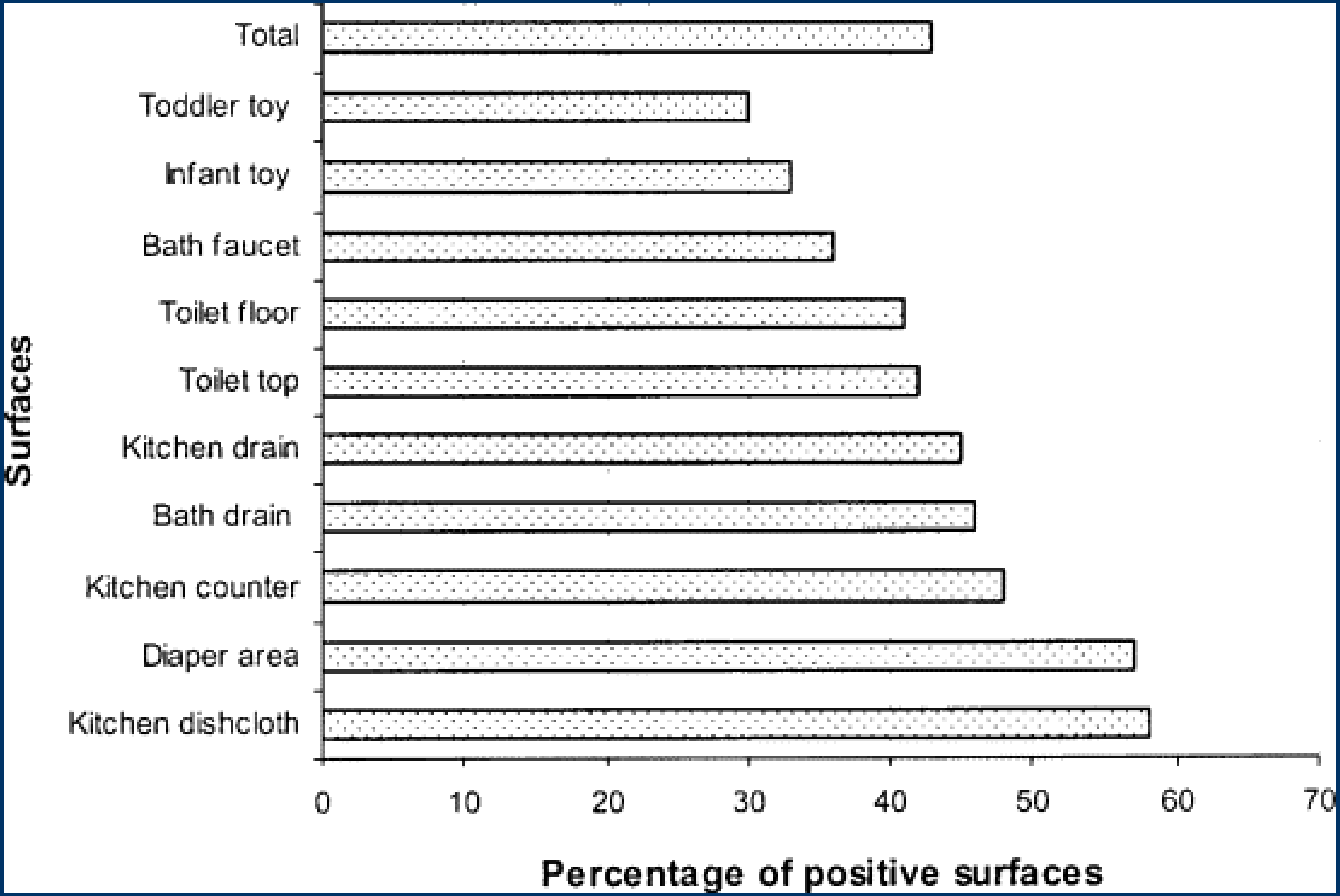
Distribution and Identification of Culturable Bacterial Flora on Monetary Coinage from 17 Countries

Country	Identification (Closest Phylogenetic Match)	Number of Bases Analyzed	Percentage Homology	GenBank Accession Number of Isolate Sequenced
Australia	*Bacillus thuringiensis/cereus*	1,015	100	AF540983
Austria	*Bacillus megaterium*	1,015	99	AY144451
Belgium	*Staphylococcus epidermidis*	982	100	—
	Bacillus litoralis	1,014	99	AF540987
Canada	*Staphylococcus aureus*	1,000	100	AY144447
France	*Streptococcus* sp.	972	99	AY144448
	Staphylococcus aureus	976	100	—
	Microbacterium sp.	999	99	AY144450
Hong Kong	*Bacillus subtilis*	970	100	AY144452
	Microbacterium sp./*Curtobacterium* sp.	949	100	AF540988
	Micrococcus luteus	1,003	100	AY144446
Israel	*Staphylococcus epidermidis*	995	100	AF540985
	Micrococcus luteus	906	100	—
Italy	*Kocaria palustris*	961	100	AY144445
Japan	*Staphylococcus hominis*	972	100	—
	Bacillus thuringiensis/cereus	970	100	—
Republic of Ireland	*Bacillus lentus*	1,015	97	—
	Staphylococcus schleiferi	981	100	AY144443
South Africa	*Kocuria palustris/Micrococcus* sp.	984	100	—
Spain	*Bacillus subtilis*	970	100	—
Switzerland	*Bacillus circulans*	1,002	99	AF540984
The Netherlands	*Paenibacillus* sp.	1,001	99	AF540982
The People's Republic of China	*Bacillus thuringiensis/cereus*	1,001	100	—
United Kingdom	*Staphylococcus hominis*	988	100	AY144444
United States	*Bacillus thuringiensis/cereus*	972	100	—

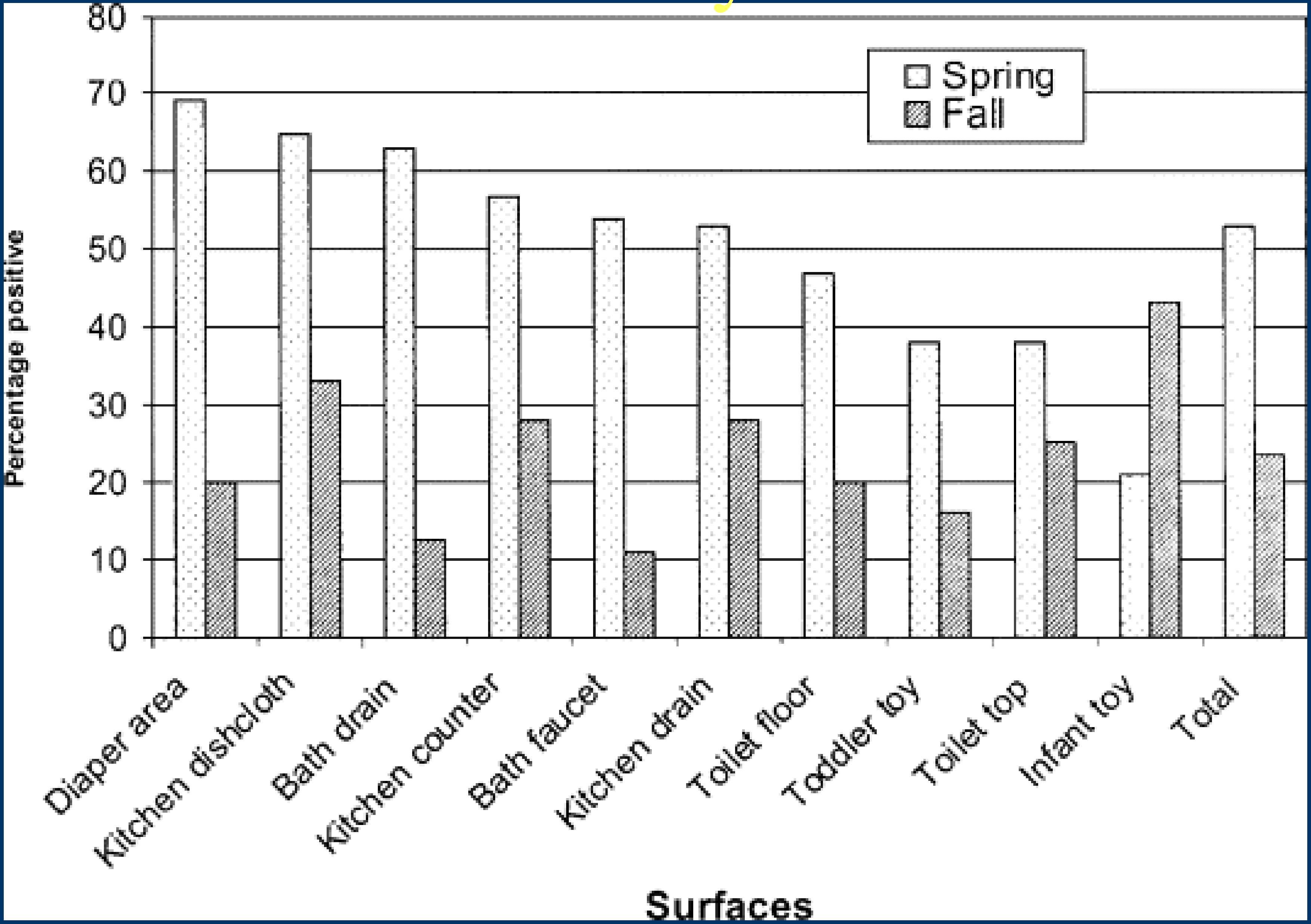
The Occurrence of Influenza A Virus on Household and Day Care Center Fomites

S.A. Boone and C.P. Gerba

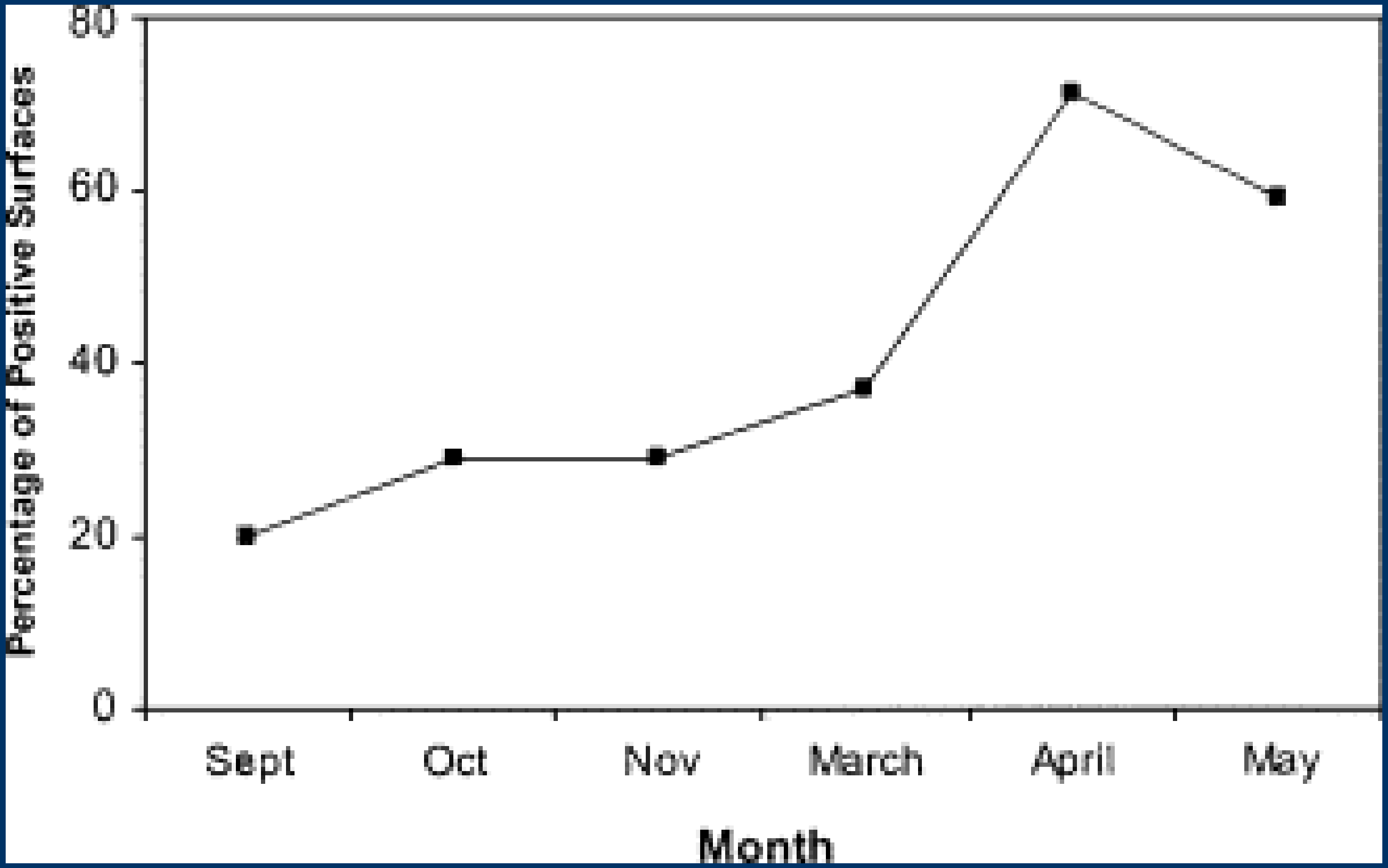
Influenza on Daycare Surfaces



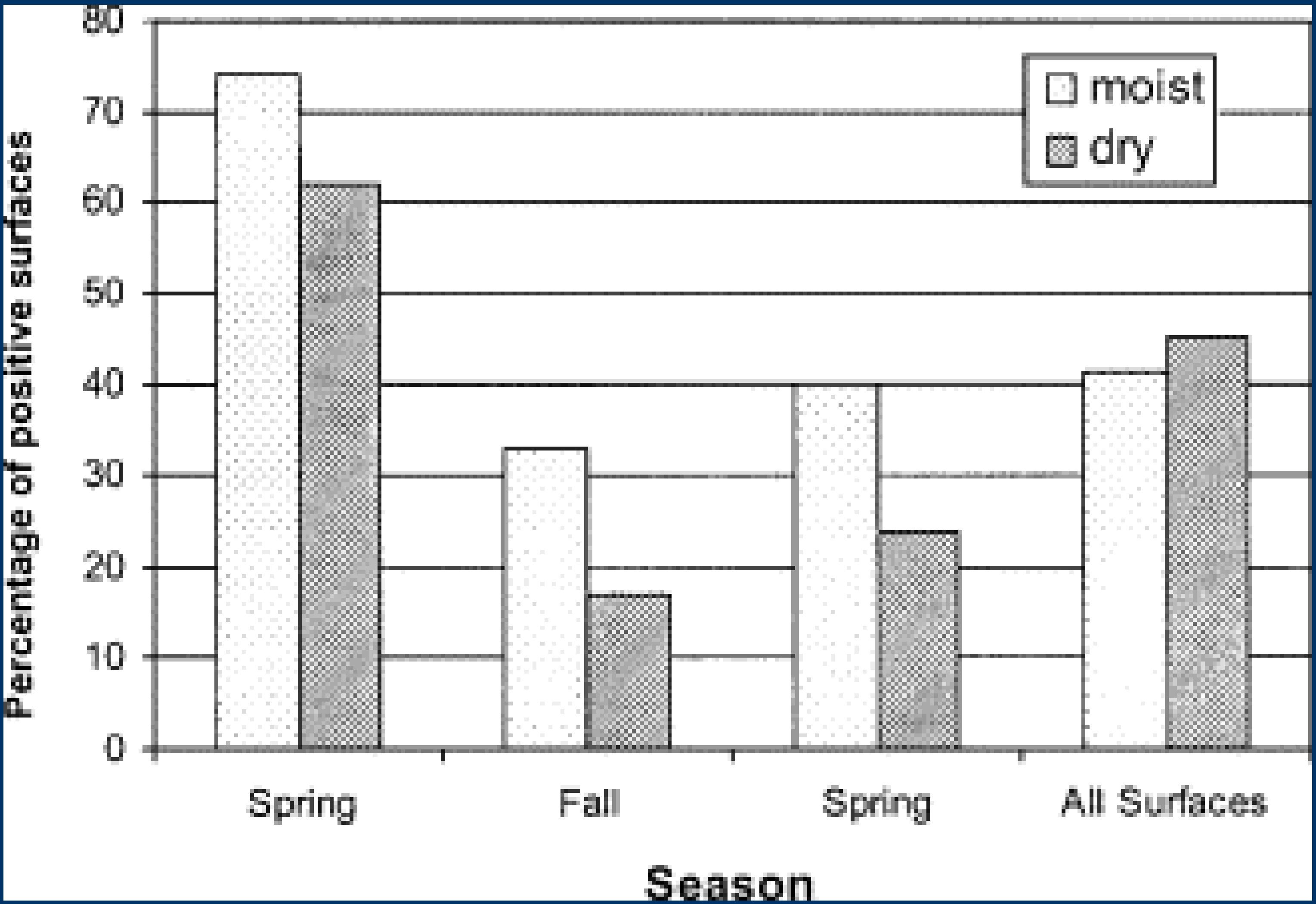
Influenza on Daycare Surfaces



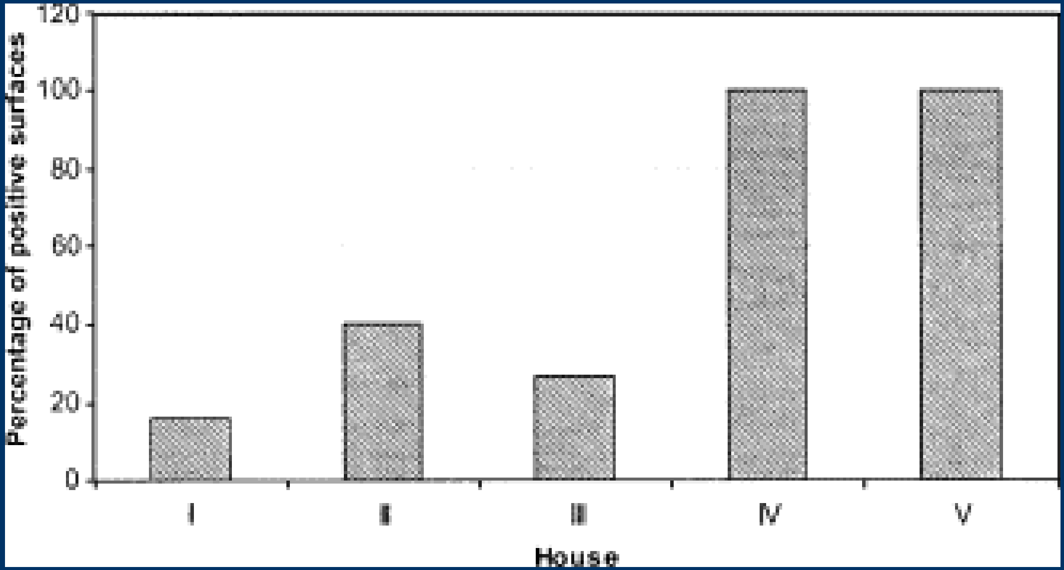
Influenza Positive Surfaces in Daycare

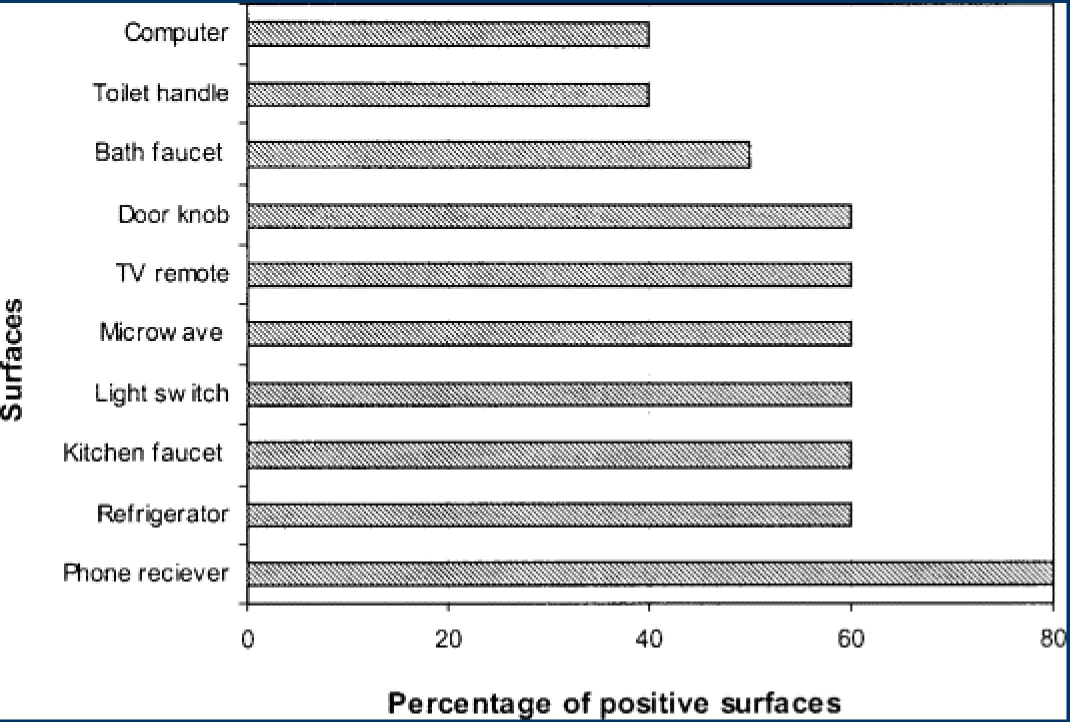


Moist vs. Dry Surfaces



In the Home


Percentage of positive surfaces
120
100
80
60
40
20
0
I
II
III
IV
V
House


Computer
Toilet handle
Bath faucet
Door knob
TV remote
Microw ave
Light sw itch
Kitchen faucet
Refrigerator
Phone reciever
Surfaces
0
20
40
60
80
Percentage of positive surfaces

Safe at Home?

- 2/3 of all viruses caught at home; more if young children present
  - At a day care center upto 50% of toys are contaminated with rotavirus
- 50-80% of foodborne illness caught at home
- Typical kitchen sink contains more fecal bacteria than typical flush toilet

Most Contaminated Areas

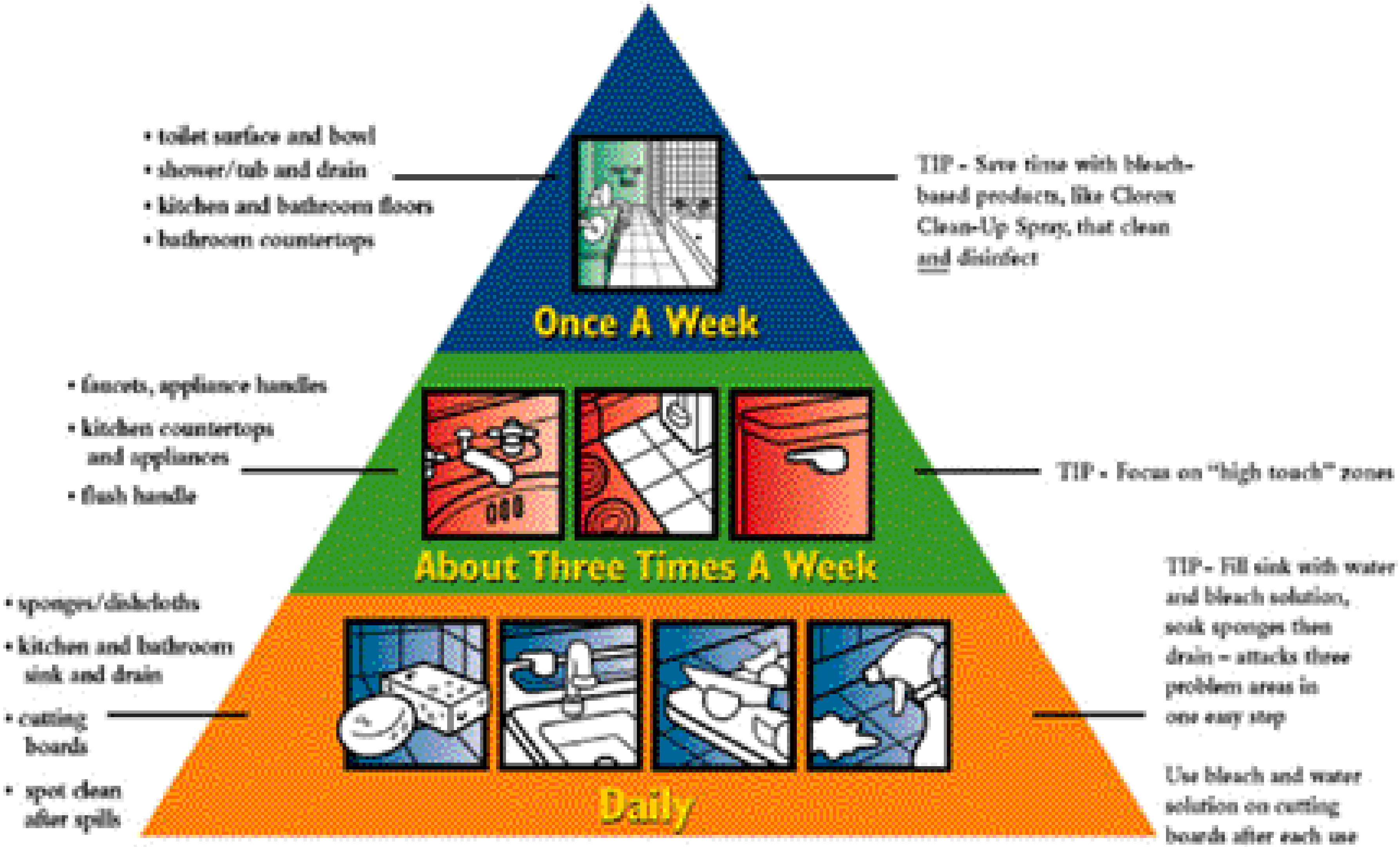
- Common Characteristics
  - Moist environments
  - Frequently touched
- 5 Worst Hot Zones
  - Sponges and Dishclothes (7 billion bacteria/sponge)
  - Sink Drain Areas
  - Sink Faucet Handles (229,000 bacteria/square inch)
  - Cutting Boards (wood or plastic ~62,000 bacteria/square inch
  - Refrigerator Handles
- Of 14 studied areas, Toilet seat was dead last for contamination

Germ Defense Pyramid

- Daily:
  - Sponges, dishclothes, sink and drain areas
  - Cutting boards after each use (esp. after meat)
  - Spills as they occur
- Several times per week:
  - High touch zones in kitchen and bathroom, e.g. toilet flush handles, faucet handles, high traffic zones on floors of kitchen and bath
- Weekly
  - Toilets, countertops, showers, tubs and drains
  - Entire kitchen and bath floors

Germ Defense Pyramid

Bleach-based cleaning routine kills 99.9% of household germs



Source: Charles Gerba, Ph.D., University of Arizona with The Clorox Company

Pathogens in Laundry

- *E. coli* and *Salmonella*
- Enterococci
- Streptococci and Staphylococci
- Acinetobacter

In Household Study:

- 100 homes
- 60% had fecal coliforms
- 10% had E.coli
- 40% of sterile cloths washed in unbleached laundry picked up fecal bacteria
- At high temperatures (131F) some bacteria (E.coli) killed, however some Salmonella survived
  - As did HAV, Rotavirus and Adenovirus

Poor Laundry Practices

- Most people use cold water or at best warm to wash
  - 5% of Americans still use hot
- People mix their loads
- People don't use much bleach
  - 15% of all wash loads use bleach (50% of white loads)
- Wash cycles are becoming shorter
  - 12 min wash, 28 min dry

Recommended Practices

- Pre-sort laundry into separate bags to limit contact (esp. in hosptials)
- Use bleach whenever possible
- Wash in hot water when possible
- Run empty bleach load after contaminated load

Toilet Trivia

- Cloacina- Roman Goddess of the Sewer
- Thomas Crapper- Inventor of the Flush Toilet
- Toilet paper usage
  - Men 2 squares/dispense
  - Women 7 squares/dispense
  - Men fold, Women crumple
- Women have the dirtiest bathrooms by far
  - Hot Zones: under sanitary napkin disposals, floor and sink; Door knobs surprisingly clean
- Average Employee uses Bathroom 3.3 times/day (women spend twice as long as men)
- Toilet stall nearest the door is the cleanest
- Best Bathrooms: Hospital Emergency Room and Fast Food Restaurants; Worst: Airports, Bus Stations
- More stalls generally = cleaner