Janet E. Allen

Static electric fields as a mediator of nosocomial infection

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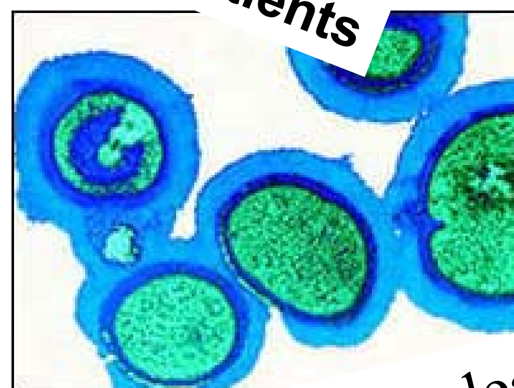
Hospital-acquired infections

Infections 'impacting' on NHS

Hospital infections cost NHS £1bn a year

Superbug hits hospital patients



Virus closes baby ward

Superbug shuts hospital ward

UK top of superbug league

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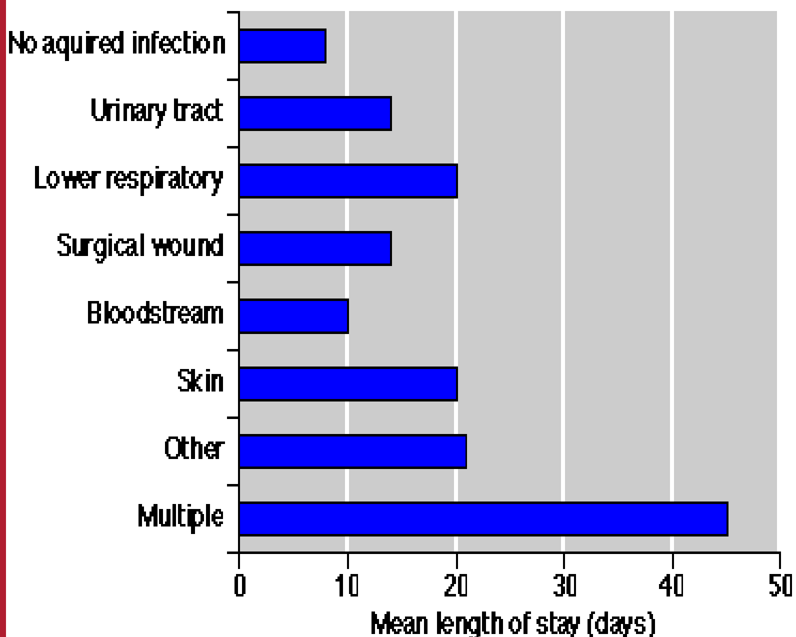
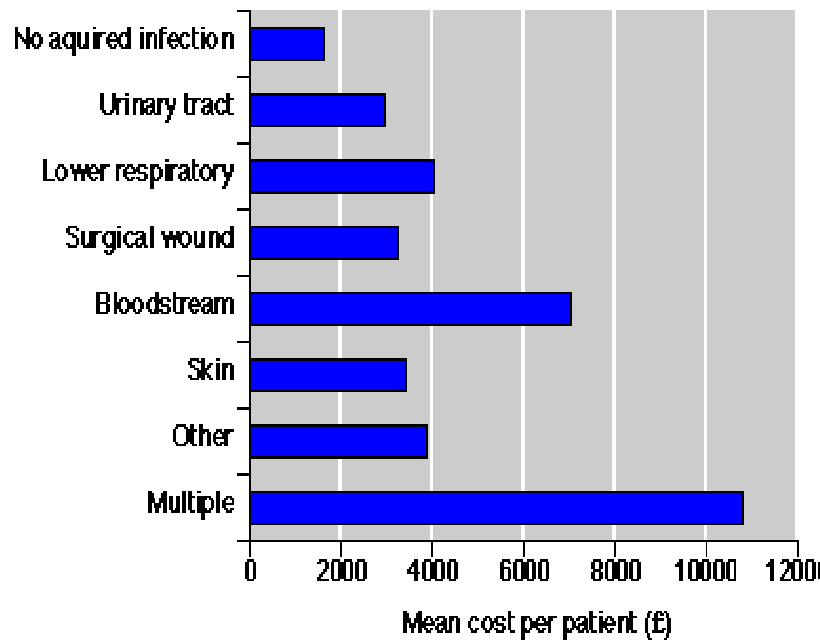
Hospital-acquired infections

The effect of hospital-acquired infection on length of stay



The effect of hospital-acquired infection on cost of treatment



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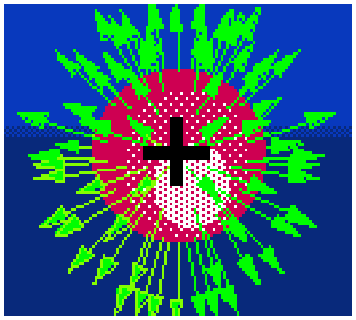
Static electric charge

Increased deposition of airborne bacteria onto surfaces carrying an electric charge might contribute to the incidence of hospital infections



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Becker R, Kristjanson A and Walker J, 1996. *Static electricity as a mechanism of bacterial transfer during endoscopic surgery.* Surgical Endoscopy, **10,** 397-399

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Charge decay times for plastic items in the BMT unit

Measurements were made of the static charge decay time for various plastic medical items in the BMT unit, Bristol, using a JCI 140C field mill meter (John Chubb Instrumentation, Cheltenham).

Item	Initial potential, kV	Time to decay to 1/e of initial potential, min
Examination glove	+ 0.270	0.1
Sterile examination glove	- 0.155	9.4
20 ml syringe, outer wrapper	- 0.238	6.5
20 ml syringe	- 0.289	6.1
Oxygen tubing	- 3.043	3.5
Plastic mattress cover	- 16.187	0.2
White plastic apron	-2.517	205.0
Green plastic apron *	+ 1.459	156.5
Plastic cupboard *	- 0.549	1.5

Temp = 19.5 C   RH = 44%
* Children's hospital ward

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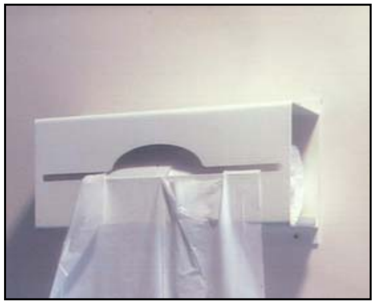
White plastic aprons

(A)



Aprons come in a roll and are placed in a plastic wall dispenser

(B)

Aprons are pulled out and torn off the roll at a perforation

(C)

The apron is worn when attending to a patient in a bone marrow transplant isolation ward

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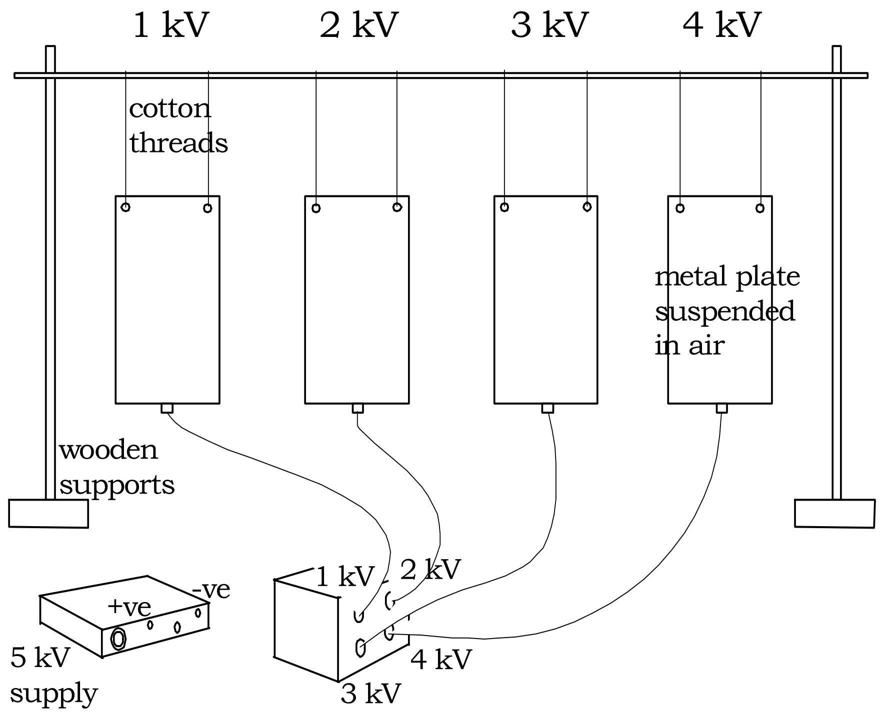
The bone marrow transplant patient

- High dose chemotherapy and radiotherapy lead to profound compromise of the immune system.
- The natural barriers of the body, particularly the mucosa lining the mouth, the bowel and the skin become pervious to infecting organisms.
- Patients are nursed in a protected environment with filtered air and nurse's very careful attention to hand washing.
- However, 95% of patients develop life-threatening infections. The majority succumb to catheter infections, necessitating replacement of plastic delivery lines.
- Hospital infection is the eventual cause of death in 10-15% of these patients.

To demonstrate dose-response between increased electric potential and deposition of airborne bacteria



Methyl cellulose filter papers were placed for 4 days: (i) at the centre of the metal plates, and (ii) half on/half off at the edge of the metal plates.

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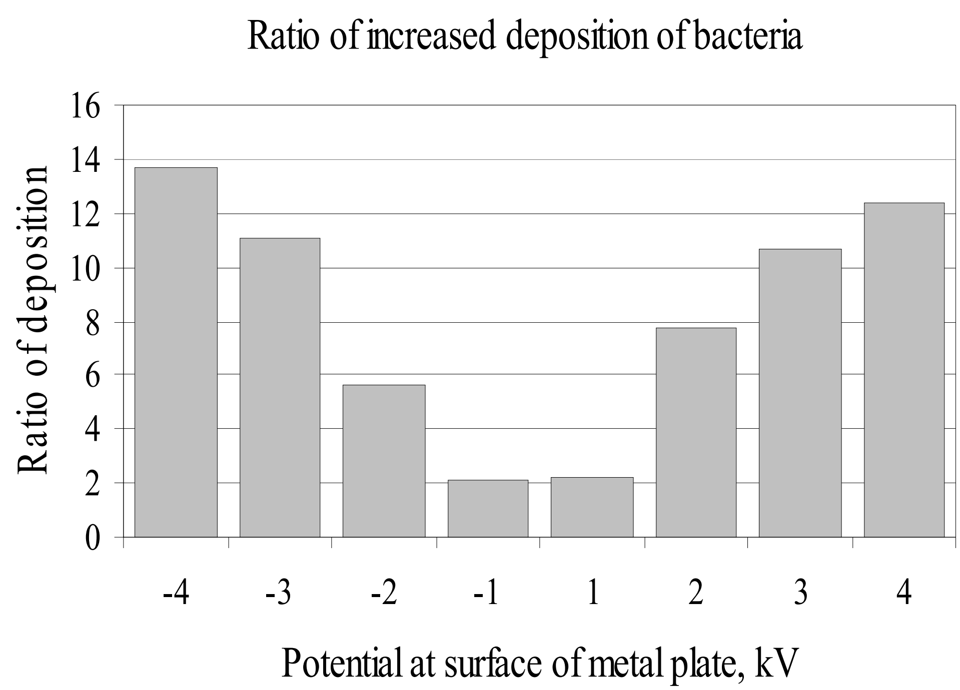
Ratio of increased deposition of bacteria at centre of the plate



2 kV
centre of plate

in air
1 m away

Excess deposition of bacteria onto the vertical surface increased with increased potential on the surface, ranging from 2 to 14-fold increase for ±1- 4 kV respectively.

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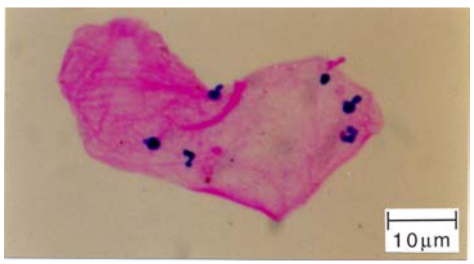
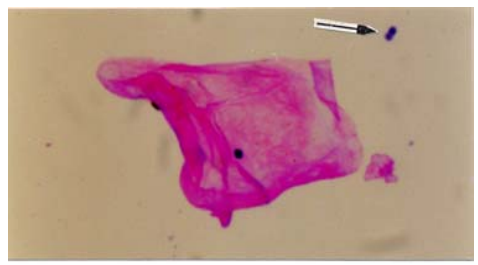
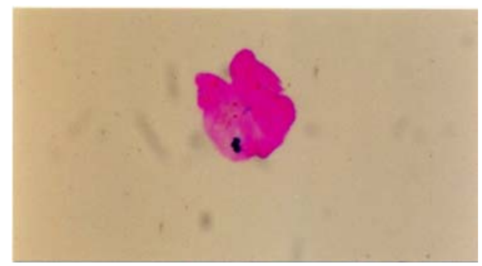
Skin Squamae

Indoors, dispersal of bacteria is mainly on skin squamae. Staphylococci are found on skin rafts of 13 μm equivalent particle diameter (Noble, 1961). Particles this size were estimated to remain airborne for an average of 17 minutes (Quebbeman, 1993).







Total output of particles carrying bacteria was around 750 – 1000 <u>per minute</u> (May K R and Pomeroy N P, 1973) and those found in hospital wards supported an average of 4 viable bacteria per scale (Lidwell *et al,* 1959).

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We need to quantify the velocity of bacteria in air due to static charge on a surface

We require knowledge of:

(1) The electrical mobility of bioaerosols

(2) Their charge state

(3) The electric field in air generated by the static charge environment

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(1) Electrical mobility of bioaerosols

Aerosol	Size (range)	Mobility $m^2 v^{-1} s^{-1}$
Rhinovirus	30 nm (25-35)	2.5×10^{-7}
Paramyxovirus	50 nm (45-55)	9.0×10^{-8}
Adenovirus	60 nm (60-75)	6.5×10^{-8}
Orthomyxovirus	100 nm (80-120)	2.5×10^{-8}
Respiratory syncytial virus	150 nm	1.5×10^{-8}
S. epidermidis	1 µm	1.0×10^{-9}
S. aureus	1 µm	1.0×10^{-9}
Small droplet	4 µm (1-4)	2.5×10^{-10}
Skin squamae	10 µm (to 15 µm)	1.0×10^{-10}
A. fumigatus (fungal spores)	4 µm	2.5×10^{-10}

Mobilities obtained using unpublished data with permission from Dr A. P. Fews

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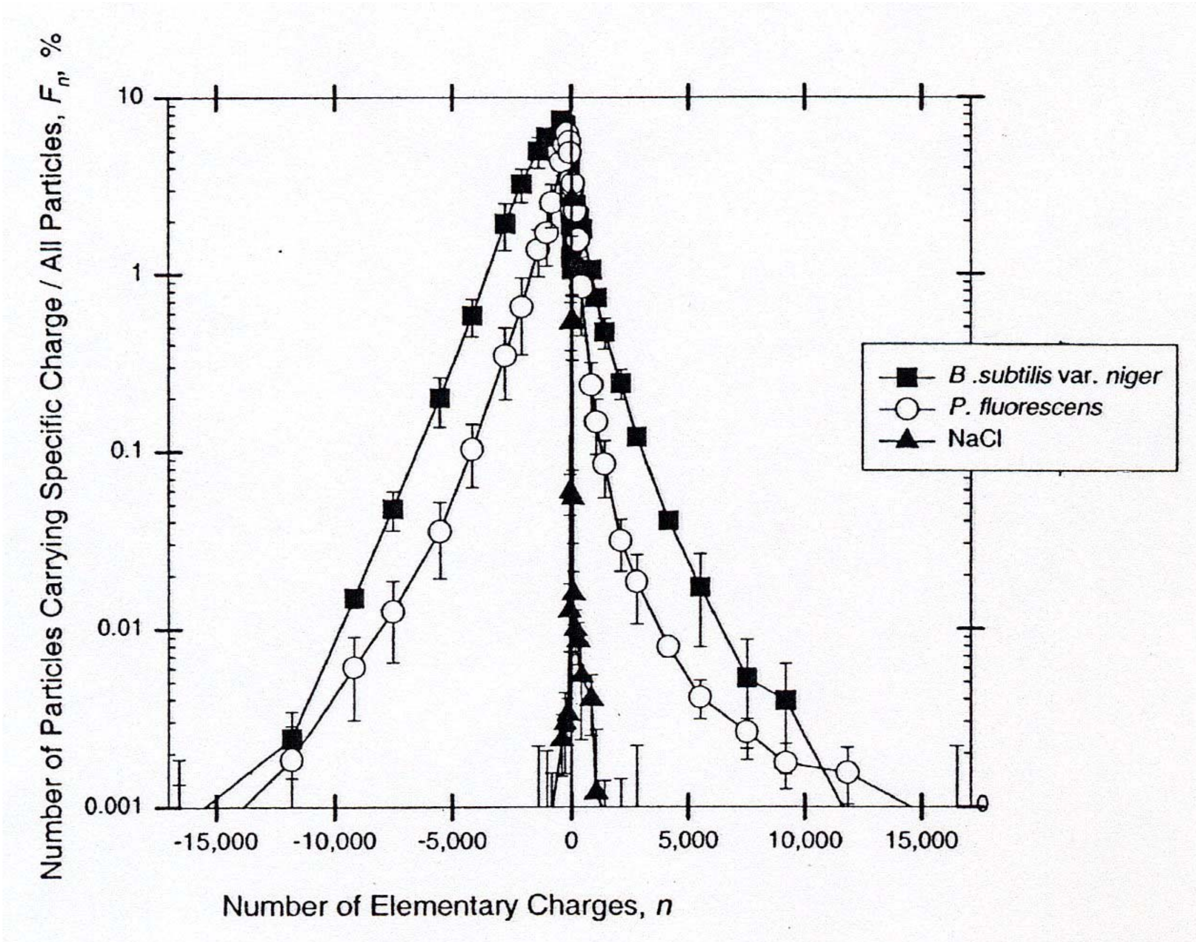
(2) Their charge state



Mainelis *et al,* 2001. Electrical charges on airborne micro-organisms. *Journal of the Aerosol Society,* **32,** 1087-1110

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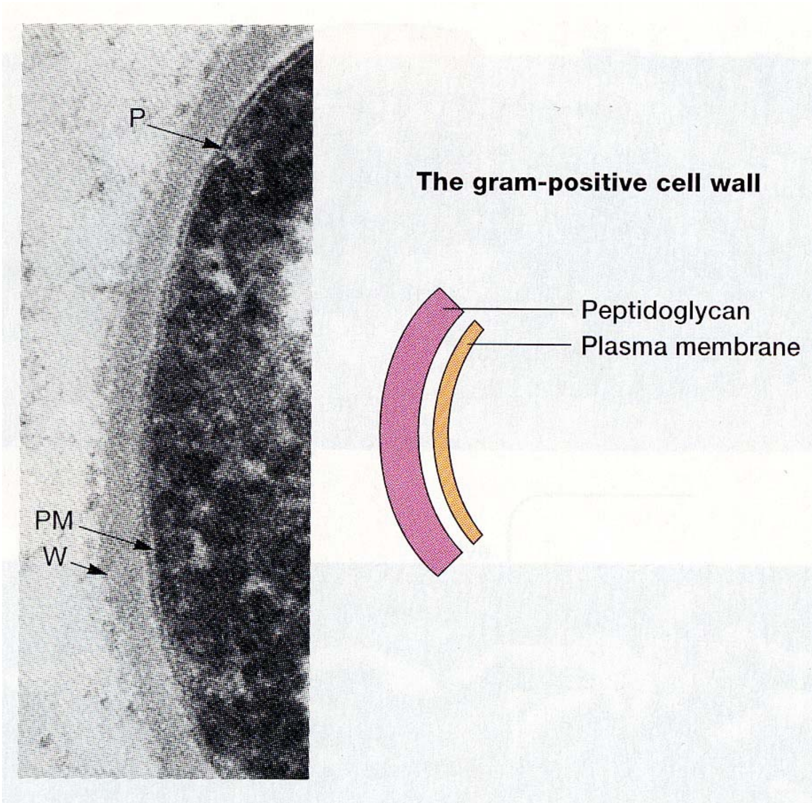
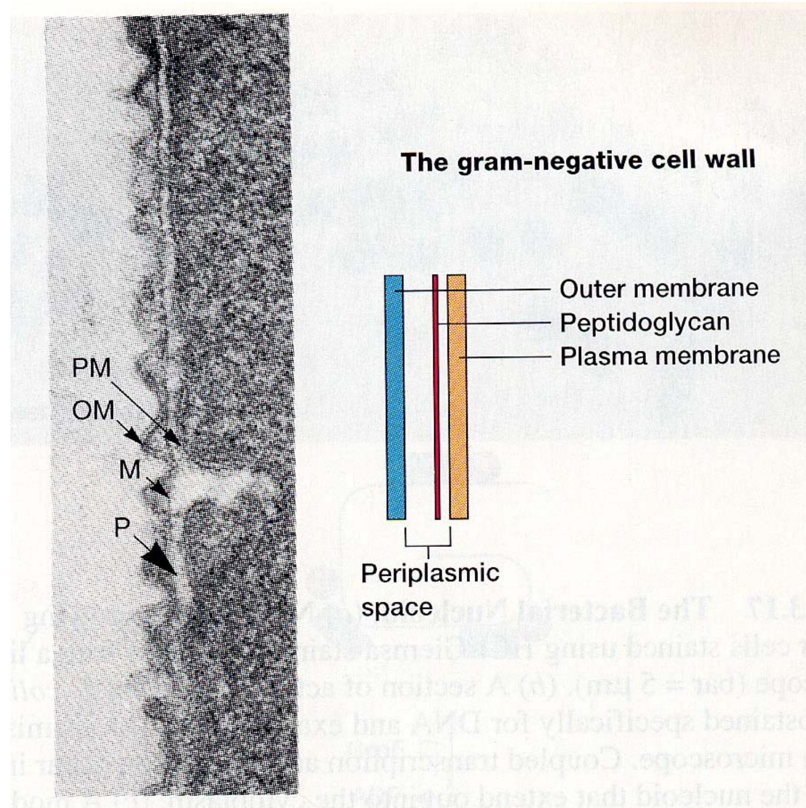
The electric charge on a bacterium consists of two components: its own **natural charge**, which can be high, and the **charge imposed** on it by the dispersion process (Mainelis *et al,* 2002)





Bacteria are classified according to staining properties under the Gram's stain: Gram +ve or Gram -ve.   Charge of bacterium from cell wall structure.

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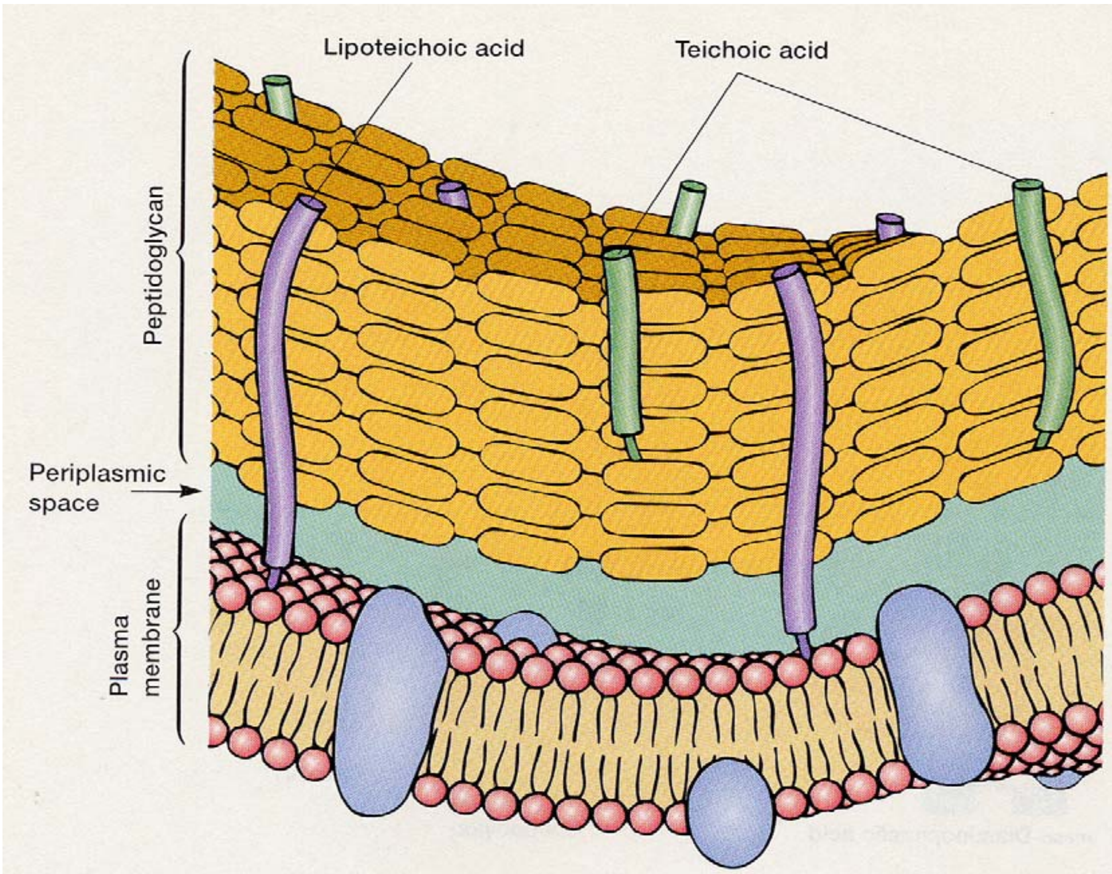
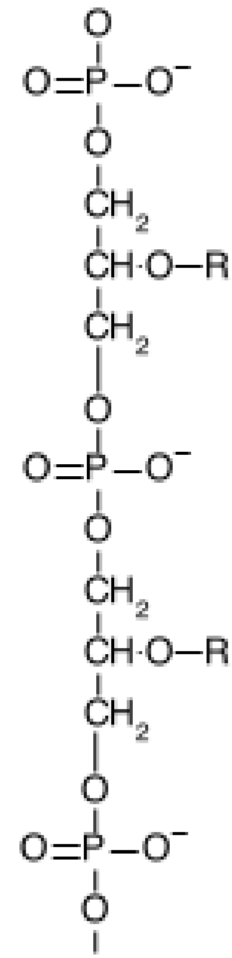
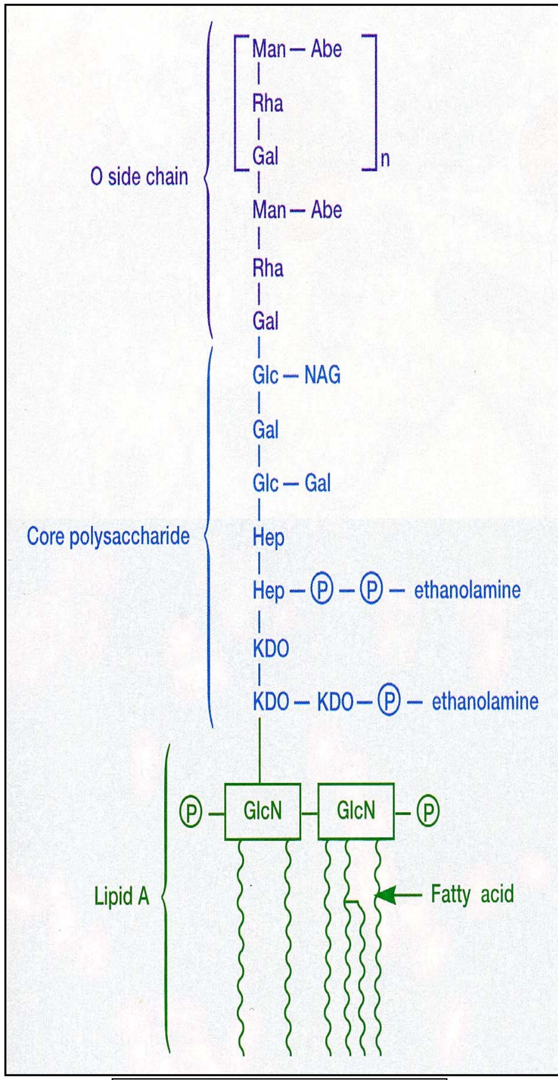
Structure of Gram +ve bacterial cell wall



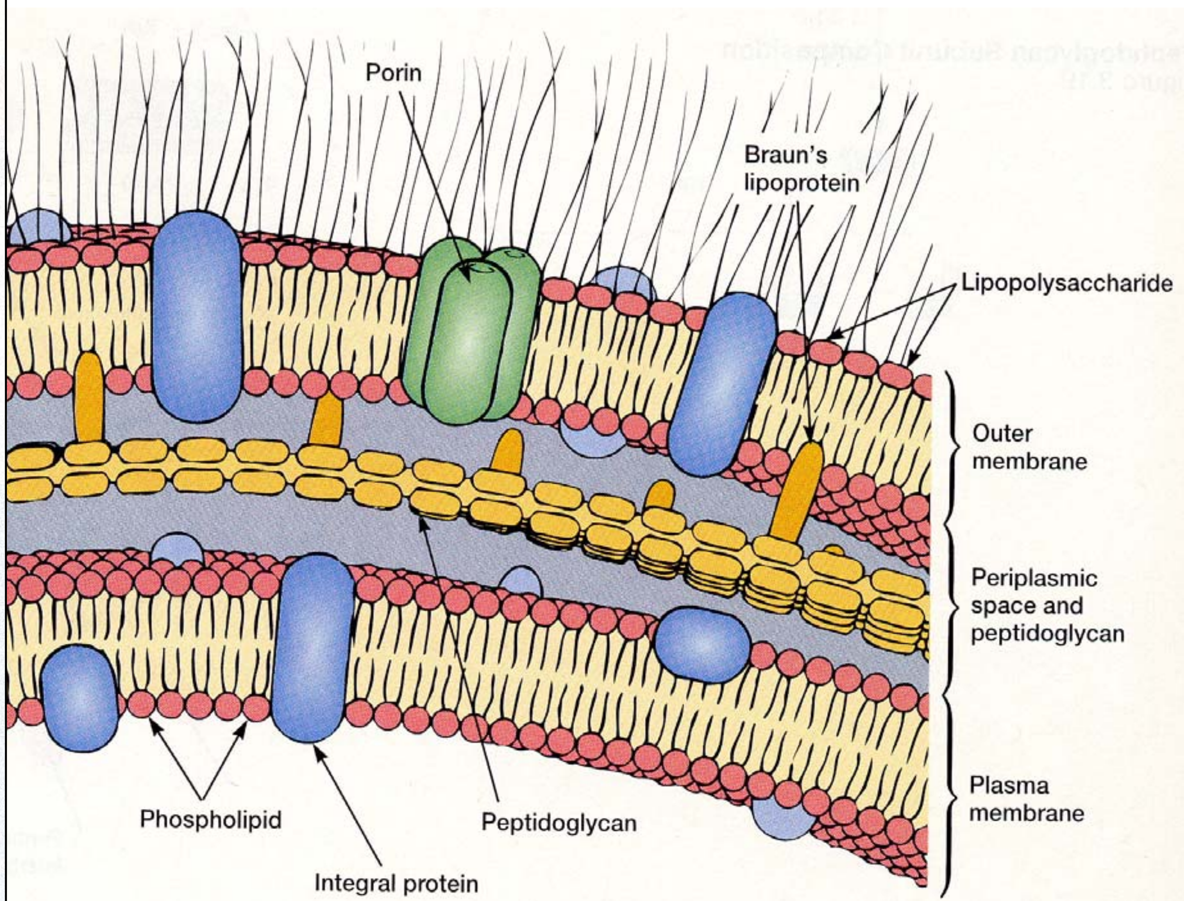


Teichoic acid

Structure of Gram -ve bacterial cell wall

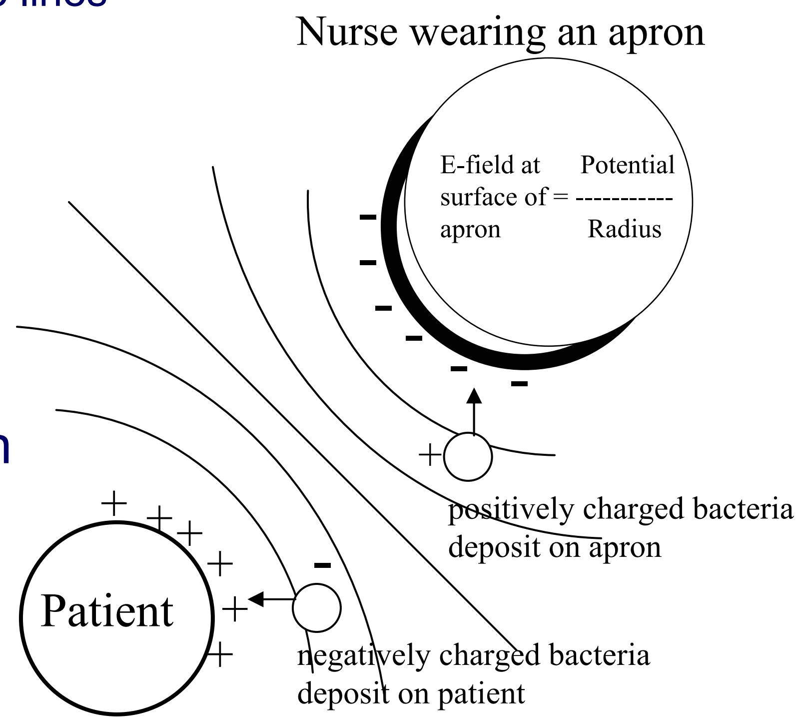


Lipopolysaccharide



(3) The electric field in air generated by the static charge environment

This simple schematic diagram illustrates the effect of the apron's electric potential on a patient. The lines represent equipotentials.



1. A nurse wearing an apron with an electric potential may induce an electric field around a patient. The closer the nurse is to the patient, the greater will be the field strength around the patient.

2. Bio-aerosol may be captured onto apron by apron's electric field

3. Bio-aerosol may be deposited directly onto the patient

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Is the velocity of the bacterium in air sufficient for capture onto the apron?

Velocity of bacteria = mobility × number of charges × E-field

Example: Particle of 10 μm diameter with 10 charges.

Potential of 1.0 kV at apron surface.

Nurse of circumference 90 cms,
Radius = 2 π r = 14.3 cms

E-field at surface of apron = $\frac{Potential}{radius} = \frac{1.0}{0.143}$ = 7.0 kV m^{-1}

Velocity of bacteria = $(1 \text{ x } 10^{-10}) \times 10 \times 7.0 \times 10^{3}$ m s^{-1}

= 0.04 cm min^{-1}

The velocity of a particle of 10 μm diameter with 10 or 10,000 charges in E-fields of different strengths

Potential at surface, kV	E-field at surface, kV m^{-1}	Number of charges	Velocity cm min^{-1}
1	7.0	10	0.04
		10,000	42
3	21.0	10	0.13
		10,000	130
6	42.0	10	2.52
		10,000	2518
9	63.0	10	3.78
		10,000	3776

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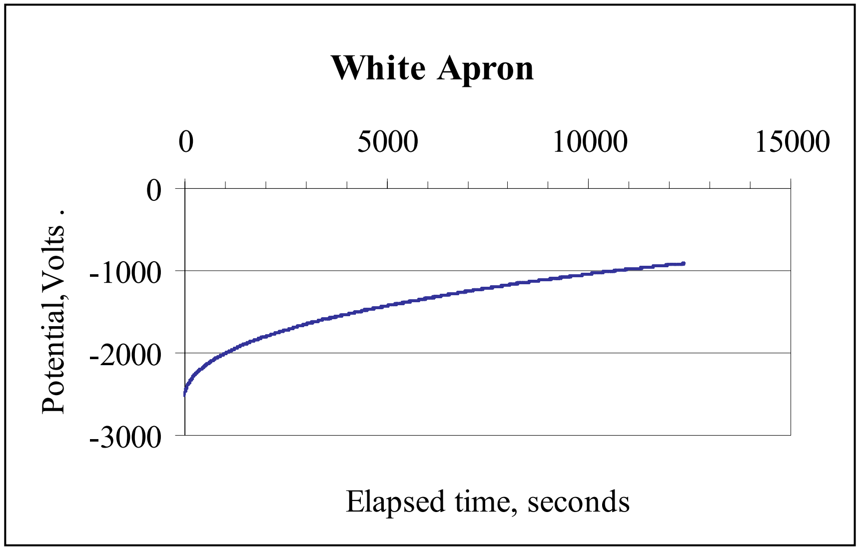
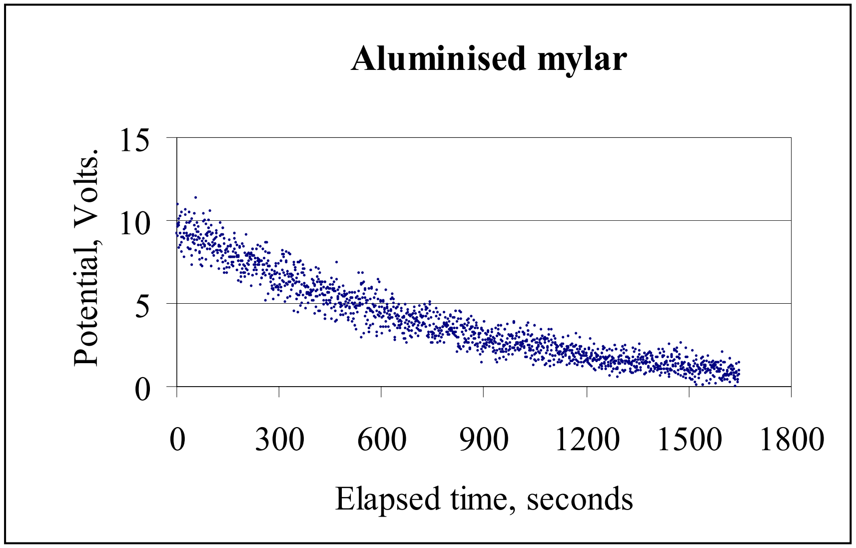
What can we do to lessen this effect?

Let's compare electric potential and charge decay times for white plastic apron with that for an apron made with conducting plastic such as aluminised mylar





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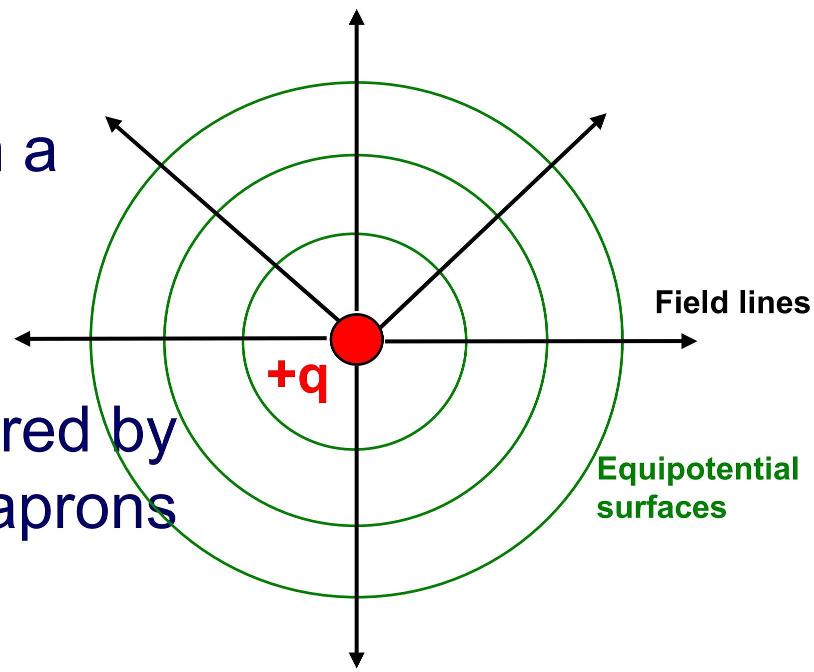
We need to measure and compare:

(1) The electrical potential at the surface of the aprons

Test aprons were made from a roll of aluminised film.



The electrical potential acquired by both conducting and plastic aprons was measured:

(i) as apron was pulled off the roll

(ii) during wearing of the apron.

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Comparison of electrical potential on aprons, results from 40 tests

Apron type	**(i) Pull - off apron** Mean, kV (range)	**(ii) Wearing apron** Mean, kV (range)
Plastic	**-5.33** (-9.90 to -2.87)	**-0.32** (-0.76 to -0.09)
Conducting	**0.00** (-0.09 to 0.06)	**0.02** (0.01 to 0.03)
Cotton	**0.16** (0.00 to 0.56)	**0.08** (0.04 to 0.20)

The highest electrical potential was induced during pull-off of the plastic aprons.

The highest electrical potential maintained during wear was found also on the plastic aprons.

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(2) Bacterial deposition on the aprons during use…

Contact agar plates were used to determine the viable bacterial count on plastic and conducting aprons before and after use.

Plates were incubated for 48 hrs at 37^{o}C and colonies counted.

Colony counts from plastic and conducting aprons.
No. tests per apron type = 270 No. apron sets = 90

	Plastic apron		Conducting apron	
	Before	After	Before	After
Total viable count	258 ± 2.2	445 ± 2.9	186 ± 1.2	238 ± 1.5
Mean per apron	0.69 ± 0.13	1.26 ± 0.17	0.42 ± 0.08	0.49 ± 0.09
% Increase		**82.6 ± 0.3**		**16.7 ± 0.1**

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Conclusion

1. Conducting aprons are less likely to attract airborne bacteria onto their surfaces compared to plastic aprons.

2. Conducting aprons carried almost zero electrical potential, even during pull-off of the apron compared with plastic aprons which acquired electric potentials as high as 9.9 kV.

3. Having made our own conducting aprons, we now need to manufacture *real* conducting aprons so that we may repeat these tests using full aprons.

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bpi.recycled products

The manufacturers of the white plastic aprons have, as a direct result of this Pilot Study, manufactured and supplied us with 5 new types of conducting and antistatic aprons for trial.

Testing of these aprons is almost complete.

One apron type is showing good antistatic properties, with less bacterial deposition on its surface.

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This work is supported by:

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Inaugurated by Diana, Princess of Wales, in memory of Jean and Paul O'Gorman

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