Innovation for infection prevention & control Learning from Pasteur's vision

G. Birgand, R. Ahmad, A. Bulabula, S. Singh, G. Bearman, E. Castro Sánchez, A. Holmes

THE LANCET

REVIEW| VOLUME 400, ISSUE 10369, P2250-2260, DECEMBER 17, 2022

Who was Louis Pasteur?

- 1822: Born in Dole, only son of a poorly educated tanner
  - Rather **mediocre student** during his years of elementary education
- 1840-1842: BA degree Royal College in Besancon, and BSc
- 1843: Ecole Normale Superieure in Paris to study chemistry
- 1845-1849: Licencie es sciences, and docteur es sciences (PhD), Professor of **physics** and **Chemistry**
- 1854: Dean & Professor of Chemistry, Faculty of Sciences Lille
- **1875: Turn his attention to medicine**
- 1881: Académie Nationale des Sciences

Louis Pasteur's discoveries

- Crystallography sediments fermenting wine: → **Alcoholic fermentation**
- Fermentation and Pasteurization
  - **Yeast responsible for forming alcohol** from sugar
  - Contaminating microorganisms → turned the fermentations sour
  - **High temperatures** kill the living microorganism → sterilize
- End of the Spontaneous Generation theory:
  - Skin of grapes source of the yeast, contamination with micro-organisms from the air
- Silk Worms → awareness of **environmental factors** on contagion
  - **Germ Theory of Disease** and Vaccination
- Immunology and vaccinology:
  - Chicken Cholera, Anthrax, Rabies (vaccine)

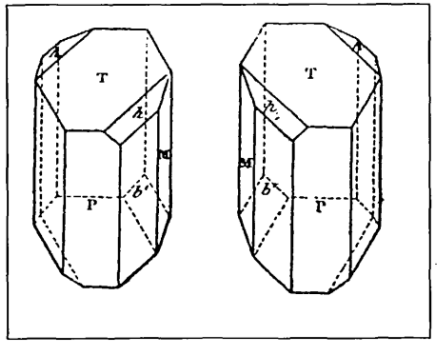


Figure 2: Pasteur's early work concentrated on optical properties of crystals

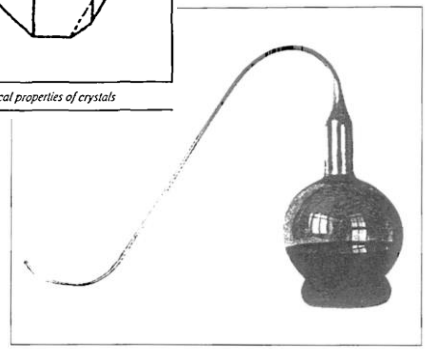
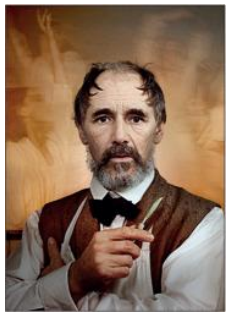
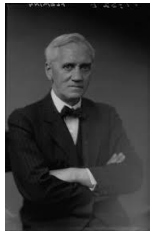


Figure 6: Pasteur used Swan-necked flasks to disprove the theory of spontaneous generation of bacteria

From 1852, the essor of hygiene





1860
Florence Nightingale (1820–1910)
Publication of notes on nursing and the environmental theory

1862
Louis Pasteur
Microbes are everywhere, in water, in the air, on objects, on the skin

1873
Robert Koch (1843–1910)
Microscopic observation of black leg fungus

1878
Louis Pasteur (1822–1895)
Pasteur's speech on asepsis addressed to surgeons from the French Academy of Sciences

1928
Alexander Fleming (1881–1955)
Discovery of penicillins

1973
Use of preventive antibiotics in clinical surgery

1986
CDC introduces universal precautions

2001
Introduction of alcohol-based hand rub in health care

2010
Implementation sciences applied to infection prevention and control

2016
WHO guidelines on surgical site infection prevention, sterilisation, and disinfection

2020
CDC begins surveillance of antimicrobial resistance in wastewater

19th century

20th century

21st century

1847
Ignace Semmelweis (1818–65)
Hypothesis of cross-transmission of puerpueral fever and introduction of chlorine for hand hygiene

1867
Joseph Lister (1827–1912)
Introduction of the concept of antisepsis

1875
Louis Pasteur
Cross-transmission of childbirth fever in the Paris Maternity Hospital

1928
Influenza vaccination opened to the general population

1969
John Charnley
Laminar airflow in orthopaedic surgery

1976
Study on the Efficacy of Nosocomial Infection Control (SENIC) project

1996
CDC Guideline for Isolation Precautions in Hospitals

2009
WHO's multimodal hand hygiene improvement strategy

2013
Whole-genome sequencing applied to infection prevention and control

2018
WHO and UNICEF call for water, sanitation, and hygiene in health-care facilities

Pasteur's vision of the hospital as a reservoir of microorganisms

Microbes are **everywhere, in water, in the air, on objects**, and on the skin, and some of them are responsible for illnesses

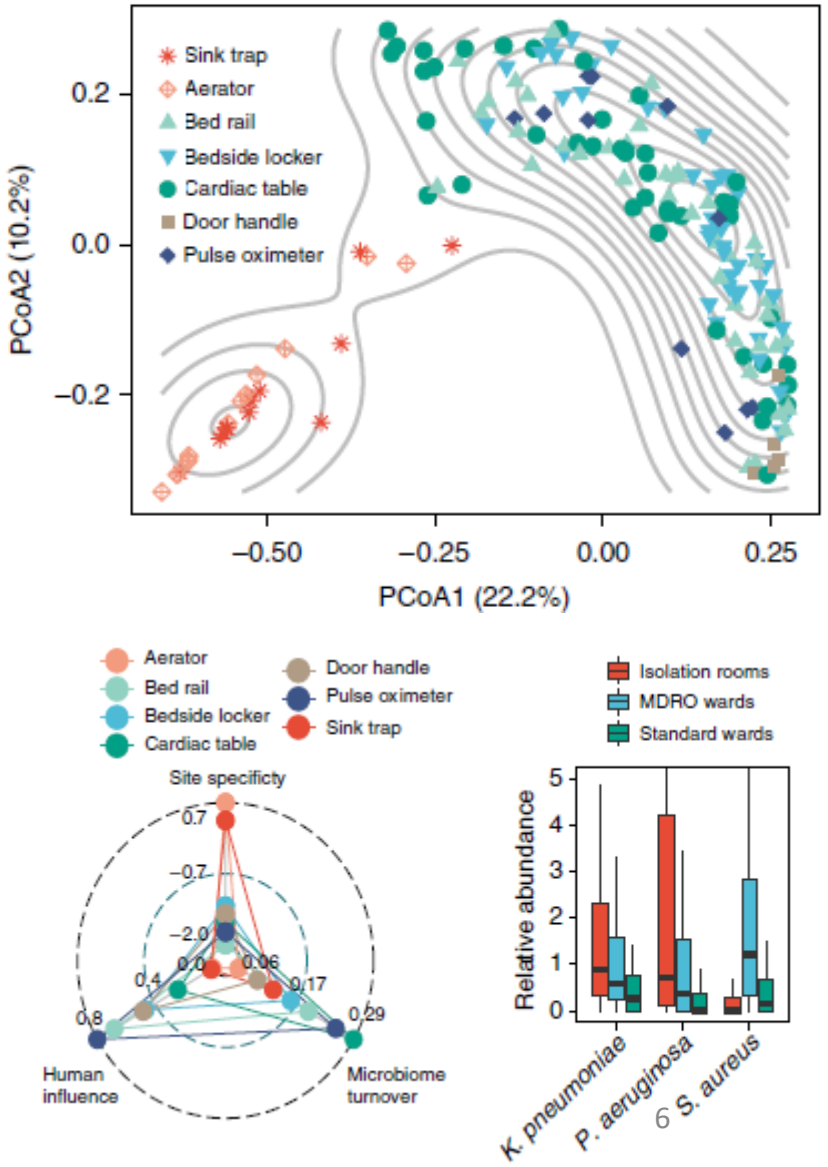
*"the dust in the **atmosphere contains microorganisms** which develop and multiply"*

*"the most putrescible liquids **remain unaltered if, after heating them, they are left protected from the air**, and therefore from these microorganisms"*

Germ transmission could result from a contaminated environment

Hospital as a reservoir of microorganisms

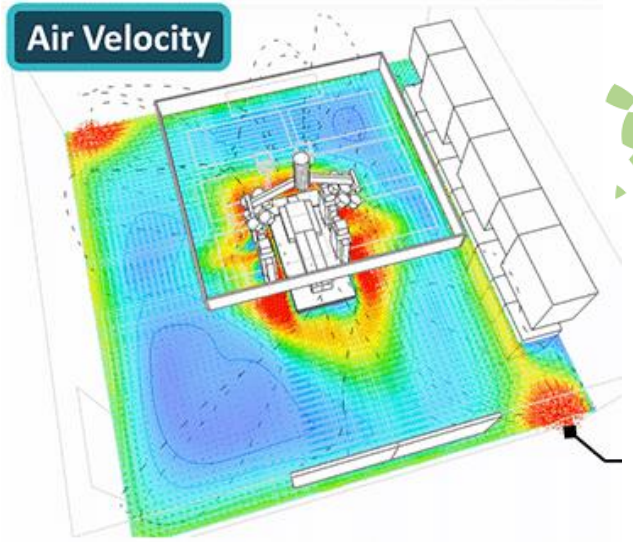
- Hospital's infrastructure/architecture influence HAI
  - Single room designs, sink, ergonomics, temperature, humidity, and the indoor ventilation system
- Distinct ecological niches for opportunistic, nosocomial pathogens and ARGs
  - Microbes persist in hospitals for extended periods (>8 years), to opportunistically infect patients
  - Significant **uncharacterized diversity of microbes** and ARG combinations
  - Fertile ground for the **evolution of ARG** combinations
  - High prevalence of ARGs plasmids enabling gene transfer across species



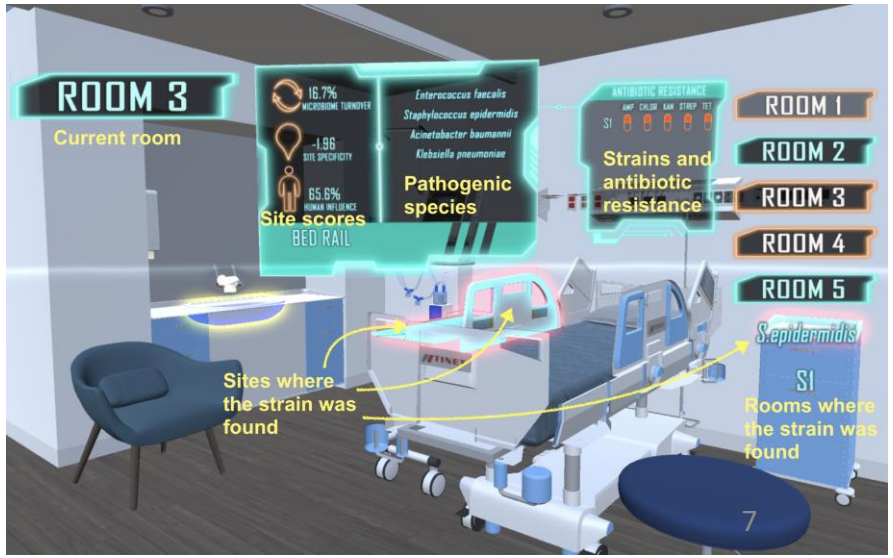
Kern Rei Chng Nature Medicine | VOL 26 | June 2020 | 941–951

Hospital as a reservoir of microorganisms

Some perspectives



- Raise attention to hospital environments
  - Systematic metagenomics surveys → SMART-IPC
  - Simulation approaches to model efficacy of design and engineering solutions
- Overcome issues on environmental disinfection
  - Implementation science
    - Methods/strategies that facilitate uptake of best practices at organisational level
  - Innovative technologies as alternative strategy for environmental hygiene
    - Disinfectants, steam, automated dispersal systems, and antimicrobial surfaces



Pasteur's vision of the hospital as an amplifier of transmission

- 1875: 64 fatalities caused by childbirth fever in the Paris Maternity Hospital

"I have this idea that the foreign body when it brings pus, which is not constant, must bring a germ, which germ would be the cause of the formation of pus."

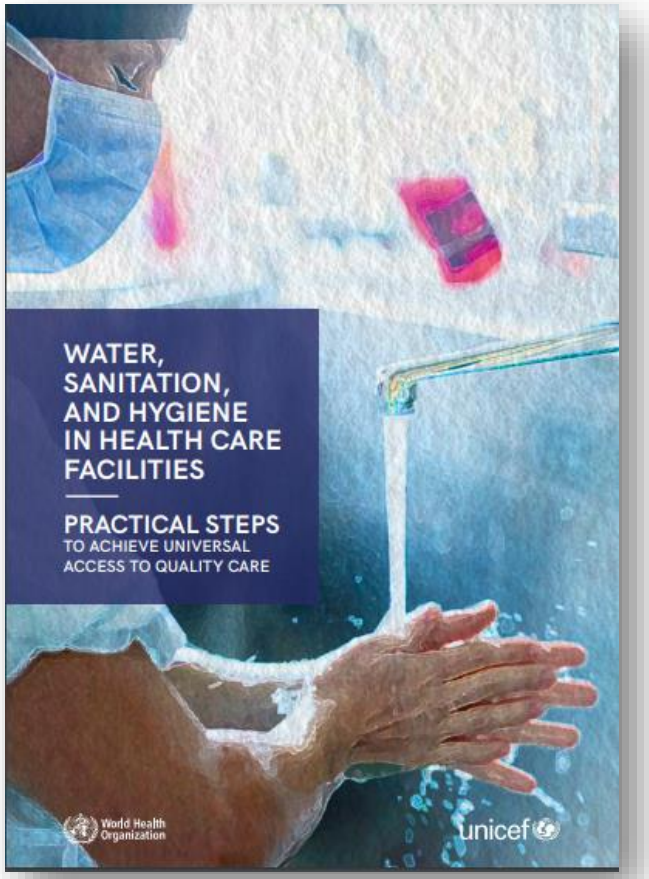
"Instead of striving to kill the microbes in the wounds, ***wouldn't it be more reasonable not to introduce any****?"*

- Strongly proposed infection being spread by physicians/attendants
  - Never mentioned that the hands could transmit the disease
  - Fanatic of hand hygiene, obsessive with hand-to-hand/hand-to-environment contact
- 1st shift on Hand hygiene: Semmelweis and Nightingale; 2nd shift: AHR

Hospital as an amplifier of transmission

Some perspectives

- Still few data regarding types of care resulting in transmission of patient flora to HCW' hands
- Adequate infrastructure: water, sanitation, hygiene (WASH)
  - Africa: 58% of health facilities with protected source of water, 22% with no sanitation services
- Enhance coordination of control measures across network of hospitals sharing patients
- Challenging global spread of emerging pathogens, ie MDR-E
  - Surveillance screening → Microbiological analysis of wastewater
  - Real-time WGS in hospitals → Smart IPC
  - Better predict risk through massive data analysis (AI)



Aseptic technique and the origins of modern surgery

In 1878, Pasteur’s speech addressed to surgeons from the French Academy of Sciences

Aseptic technique and the origins of modern surgery

- At the same period in England, Joseph Lister
  - Putrefaction = same principles as fermentation
  - Concept of antisepsis: spray of carbolic acid

  ↘ in-hospital death rate from 40% to 15%
- Concept of asepsis by Pasteur:
  - Prevent pathogens from entering the wound
- 1883: Octave Terrillon, French surgeon
  - Sterilised instruments and dressings by boiling or by dry heat autoclave

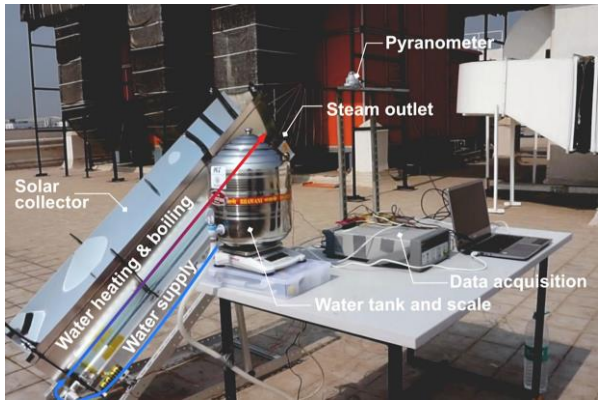
Aseptic technique

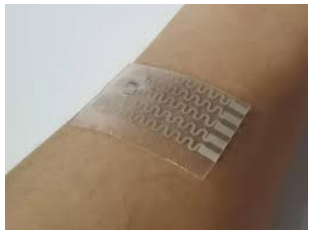
Some perspectives

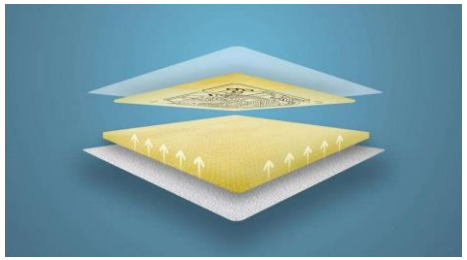
- Remaining debates/controversies
  - Role of intraoperative environment (ventilations, devices, behaviours)
  - Skin prep/decolonization: effectiveness & collateral damages

  →Alternative concepts (ie, vaccination or immunotherapy)
- Innovative sterilisation methods
  - Sunlight heat: widespread solutions, sustainable
- Innovations in dressing types
  - Negative pressure wound therapy, silver/antiseptic dressings
  - Practical tools: ideal cost-effective dressing /type of wound
  - Smart wound dressings with sensors assessing the healing process

Sunlight sterilisation, MIT





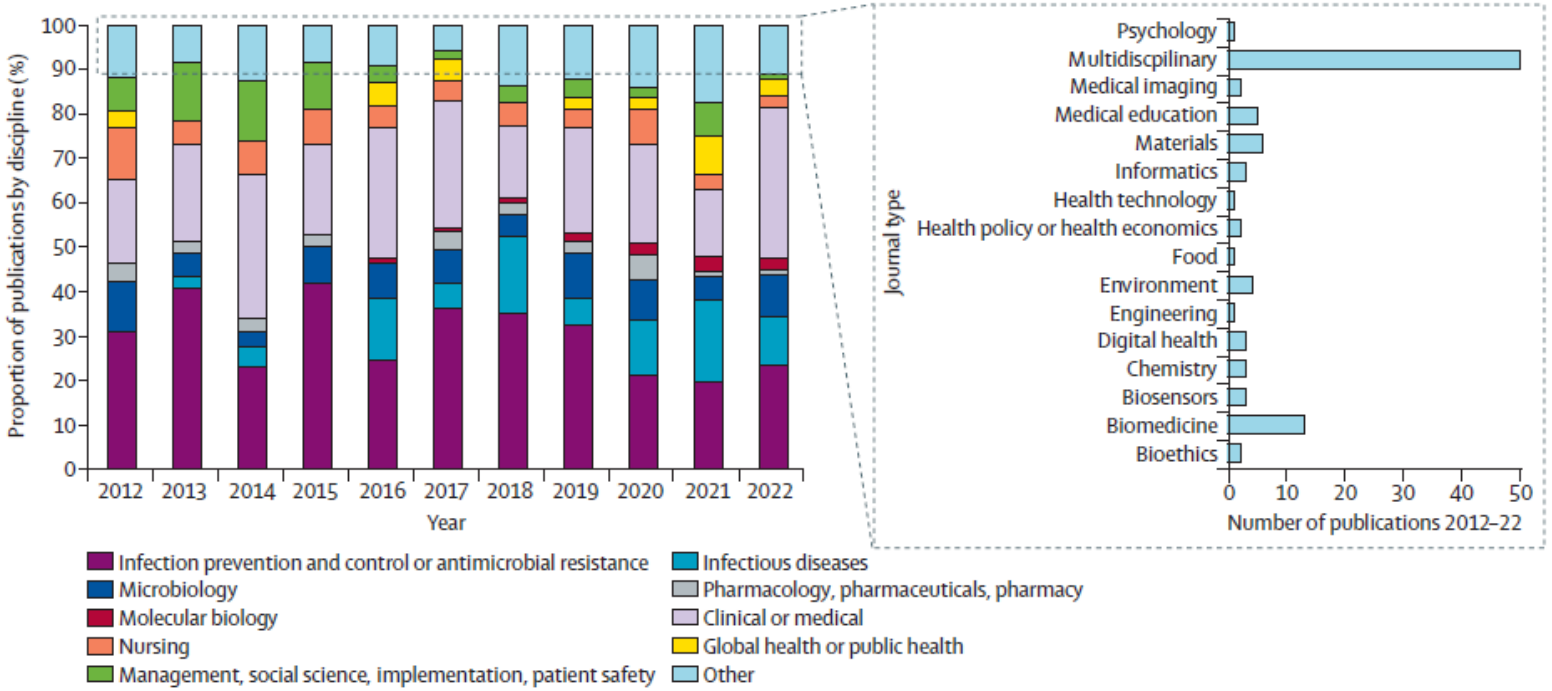


Smart dressings

Collaborative work, clinicians, scientists from physics, materials science, nanoengineering, stem cell biology to manufacture dressings that serve as physical, chemical, and antimicrobial barriers, and devices for growth-factor and cell delivery

Multidisciplinary and cross-boundary working and leadership

Pasteur brought together engineering, chemistry, and medicine



- Cross-boundary translation of innovations to medicine

→ Human factors in safety cultures of institutions and systems

  - Multimodal strategies, social sciences & roles of social norms behaviours in good IPC practices
  - Spread of Implementation sciences

- Learning between HIC and LMICs is still skewed towards high-income settings
- System level innovations for new technologies and processes
- Innovation for embedding and scaling up interventions that have a well-established evidence base

Pasteur's vision of health-care settings as a platform to spread public health education

*"The **hospital must be the place of public education on hygiene**, helped in this by social workers and nurses visiting dispensaries who go to meet suffering humanity"*

- Pedagogical innovations
  - Virtual reality, simulation, arts-based approaches
- Education and self-efficacy of patients and citizens
  - Needs to explore cultural/contextual sensitivities to participation
- Determinants of suboptimal health literacy
  - Addressing misinformation/disinformation

- Integrative models
  - Hospitals + primary/secondary providers, local authorities
  - Holistic policy responses to complex causes/consequences of infections
- Interventions to arrest the emergence of infectious threats
  - Prosocial behaviours encouraged by social cohesion, greater equity in access, reduced inequalities in outcomes

Vaccines as armoury to protect health services and patients

Indirect positive effect of Pasteur's discovery of vaccines

Vaccination to prevent risk to HCW/patients, keeps health-care functioning

- COVID-19: up to 77% ↘ emergency department visits among >75 years
- Influenza vaccination: cost-effective vs absenteeism, presenteeism, medical care
- Barriers: Vaccine hesitancy, resources of occupational health services

Vaccines, passive immunisation, monoclonal therapies to ↘ burden of HAIs

- Effective vaccines for *S aureus* or gram-negative bacteria challenging (endogenous)
- *C difficile* infections, seems to be near
- Antibody-based therapy: pathogen-specific antibacterial alternative to antibiotics

Vaccines as armoury to protect health services and patients

Inc…nes

Vaccination t…unctioning

- COVID-19…rs
- Influenza…edical care
- Barriers: …

Vaccines, pas…den of HAIs

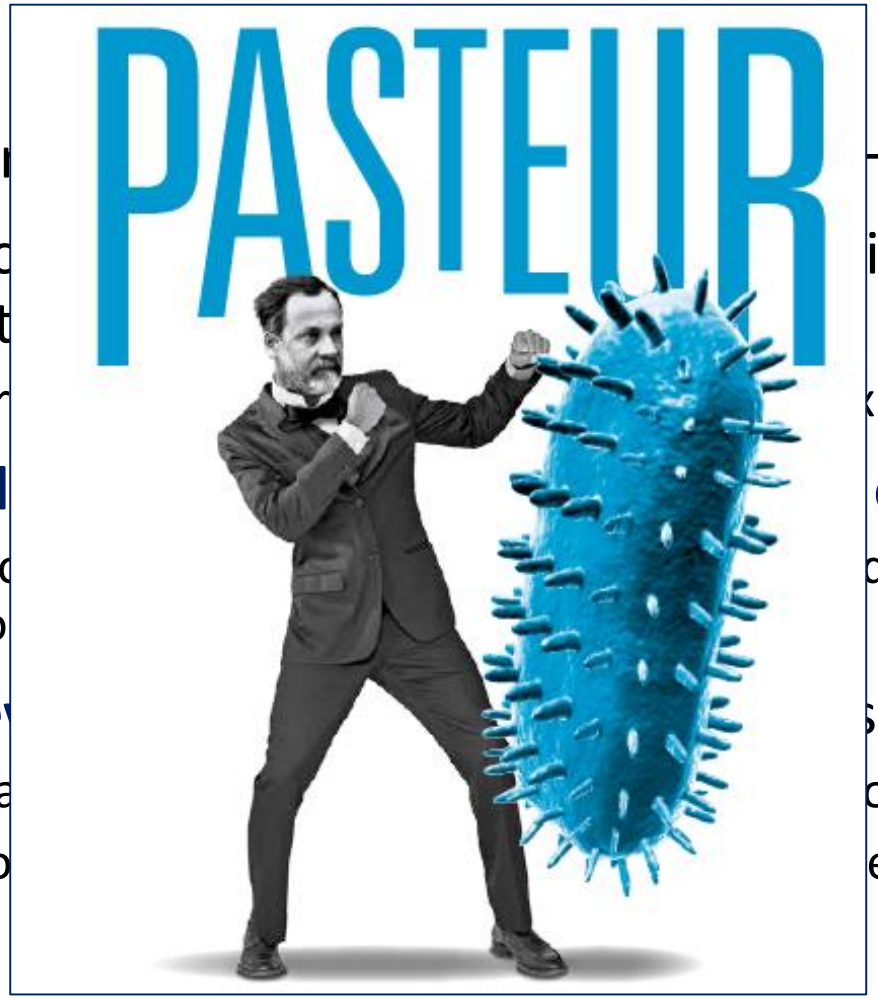
- Effective …endogenous)
- *C difficile*
- Antibody-…antibiotics

Future challenges to infection control

- Current IPC probably prevents only **up to 55–70%** of all HAI
- Ageing populations, increasingly sicker, multiple comorbidities, therapies modifying immune system and personal microbiota
  - Outpatient and day-care procedures grow increasingly complex and invasive
- Requirement for **broad, collaborative, multidisciplinary efforts**, creative thinking
  - Informatics, engineer for electronic medical records, sensor badges, PPE, antisepsis, disinfection, sterilisation, and cleaning, microbiome
- **Precision infection prevention** might offer opportunities to tailor IPC measures
  - ML assessing multiple available data to prioritise IPC interventions
  - Virtual IPC platforms to assist rural / low resource settings → Real-time, expert consultation
  - One Health approach

Future challenges to infection control

- Current IPC probably pr… HAI
- Ageing populations, inc… idities, therapies modifying immune syst…
  - Outpatient and day-car… and invasive
- Requirement for **broad**… **efforts**, creative thinking
  - Informatics, engineer fo… dges, PPE, antisepsis, disinfection, sterilisatio…
- **Precision infection prev**… to tailor IPC measures
  - ML assessing multiple a… ons
  - Virtual IPC platforms to… eal-time, expert consultation
  - One Health approach



"Let me tell you the secret that has led to my goal.
My strength lies solely in my tenacity."

CPias Pays de la Loire

RéPiAS Réseau de Prévention des Infections Associées aux Soins
PRIMO

Nantes Université

EUCIC EUROPEAN COMMITTEE ON INFECTION CONTROL
European Society of Clinical Microbiology and Infectious Diseases

EUCIC

@EUCIC1

Edit profile

Thank you

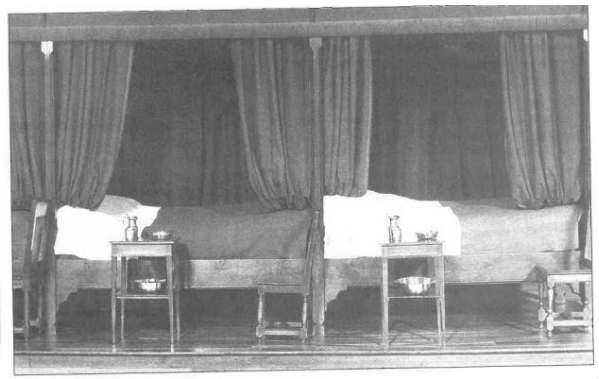
European Committee on Infection Control @ESCMID
@EUCIC1

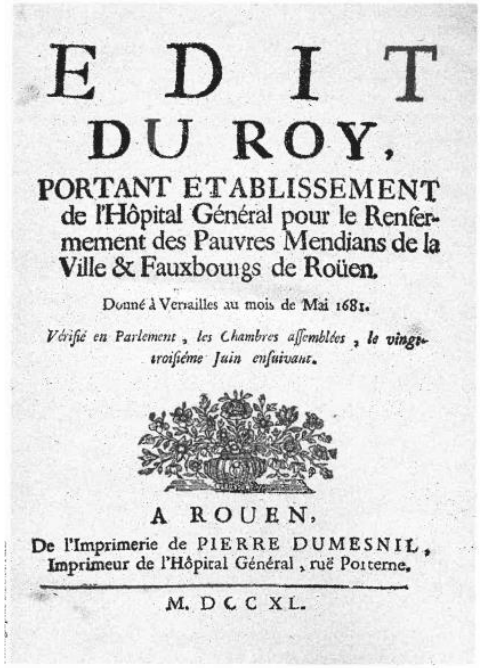
EUCIC @escmid aims to strengthen infection control and preventive measures in European countries to reduce the burden of healthcare-associated infections

Evolution of Hygiene and IPC

- Middle age: Exemplar Hygiene of hospital
- 17-18th century: the decline of Hygiene
  - Large dormitories, poor and sick people with older people, children, and healthy alike
- From 1786: Start of modern hygiene
  - Architectural measures to improve air quality, but infections persisted and continued to kill
- 1852 - early 20th century: the essor of hygiene
  - Ignaz Semmelweis on hand hygiene,
  - 1850 to 1975: triumph of the laboratory medicine

VUE ACTUELLE DE L'HÔTEL-DIEU DE BEAUNE
CONSTRUIT ENTRE 1443 ET 1451.





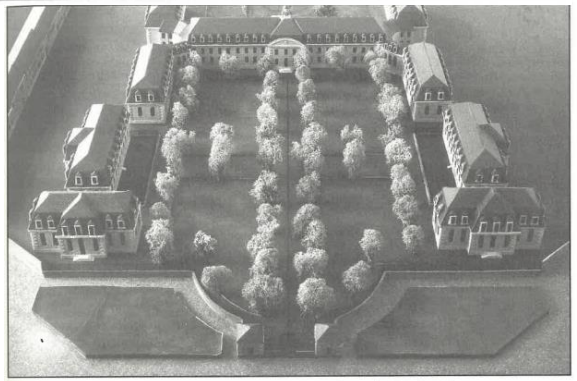
E D I T
DU ROY,
PORTANT ETABLISSEMENT
de l'Hôpital Général pour le Renfermement des Pauvres Mendians de la Ville & Fauxbourgs de Roüen.

Donné à Versailles au mois de Mai 1681.

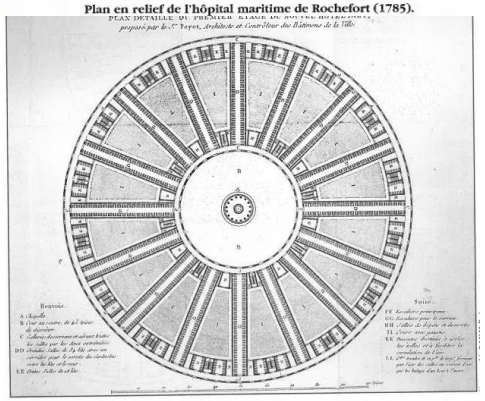
Vérifié en Parlement, les Chambres assemblées, le vingt-troisiéme Juin ensuivant.

A ROUEN,
De l'Imprimerie de PIERRE DUMESNIL,
Imprimeur de l'Hôpital Général, ruë Poiterne.

M. DCC XL.



Plan en relief de l'hôpital maritime de Rochefort (1785).

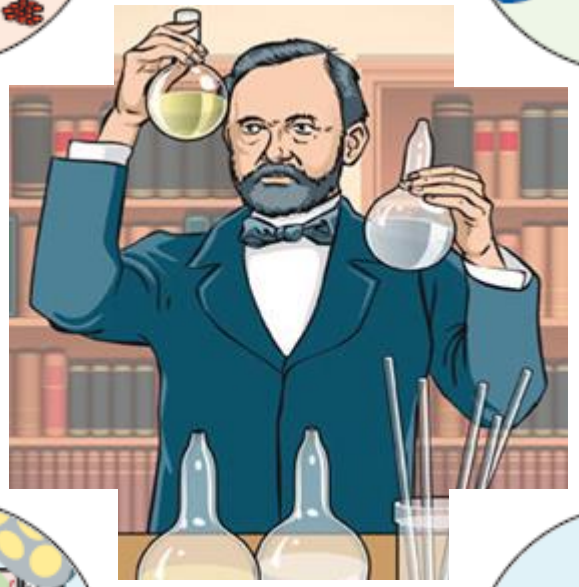


Pasteur's vision on the innovation for infection prevention and control

Pasteur's vision of the **hospital as a reservoir of micro-organisms**

Pasteur's vision of the **hospital as an amplifier of transmission**

Cross-disciplinary and cross-boundary working and leadership



Pasteur's vision of **healthcare settings as a platform to spread public health education**

Aseptic technique and the origins of modern surgery

Vaccines as armoury **to protect health services and patients**