ASHRAE Hong Kong Chapter - Webinar:
23 Apr 2020 (Thu)

Planning and preparing health care facilities for the COVID-19 pandemic

規劃和準備針對2019冠状病毒病大流行的醫療保健設施

Ir Dr. Sam C. M. Hui

Regional Vice Chair – Government Affairs, ASHRAE Region XIII

E-mail: sam.cmhui@gmail.com

http://ibse.hk/200423_ASHRAE-HKC_Webinar_SamHui.pdf

Apr 2020

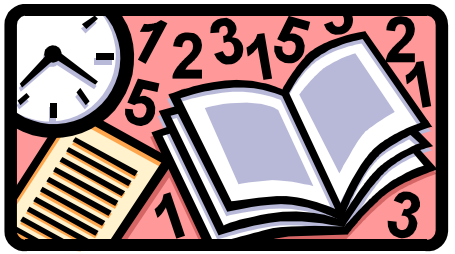
Our appreciation for healthcare and frontline workers
感謝醫護及前線人員

Work Together, Save Lives

Engineers support you in health care facilities
工程師在醫療保健設施中為您們提供支援

攜手合作
拯救生命

About the Speaker



- ***Ir Dr. Sam C. M. Hui*** *許俊民 博士 工程師*

  - PhD, BEng(Hons), CEng, CEM, BEAP, BEMP, HBDP, MASHRAE, MCIBSE, MHKIE, MIESNA, LifeMAEE, AssocAIA
    - CEng = Chartered Engineer
    - CEM = Certified Energy Manager
    - BEAP = Building Energy Assessment Professional
    - BEMP = Building Energy Modeling Professional
    - HBDP = High-performance Building Design Professional
    - LifeMAEE = Life Member, Association of Energy Engineers
    - AssocAIA = Associate Member, American Institute of Architects
  - ASHRAE Distinguished Lecturer (2009-2011)
  - President, ASHRAE Hong Kong Chapter (2006-2007)
  - 29 years teaching & research experience at HKU, CityU and THEi

ASHRAE Overview

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(Source: https://www.ashrae.org/professional-development/ashrae-certification)

ASHRAE Hong Kong Chapter – Webinar

Planning and preparing health care facilities for the COVID-19 pandemic

- **Learning Objectives:**
  - Understand the engineering principles for health care facilities related to the COVID-19 pandemic
  - Explain the strategy for planning and preparing health care facilities and hospitals
  - Appreciate the key issues and factors for emergency management in health systems

ASHRAE Hong Kong Chapter

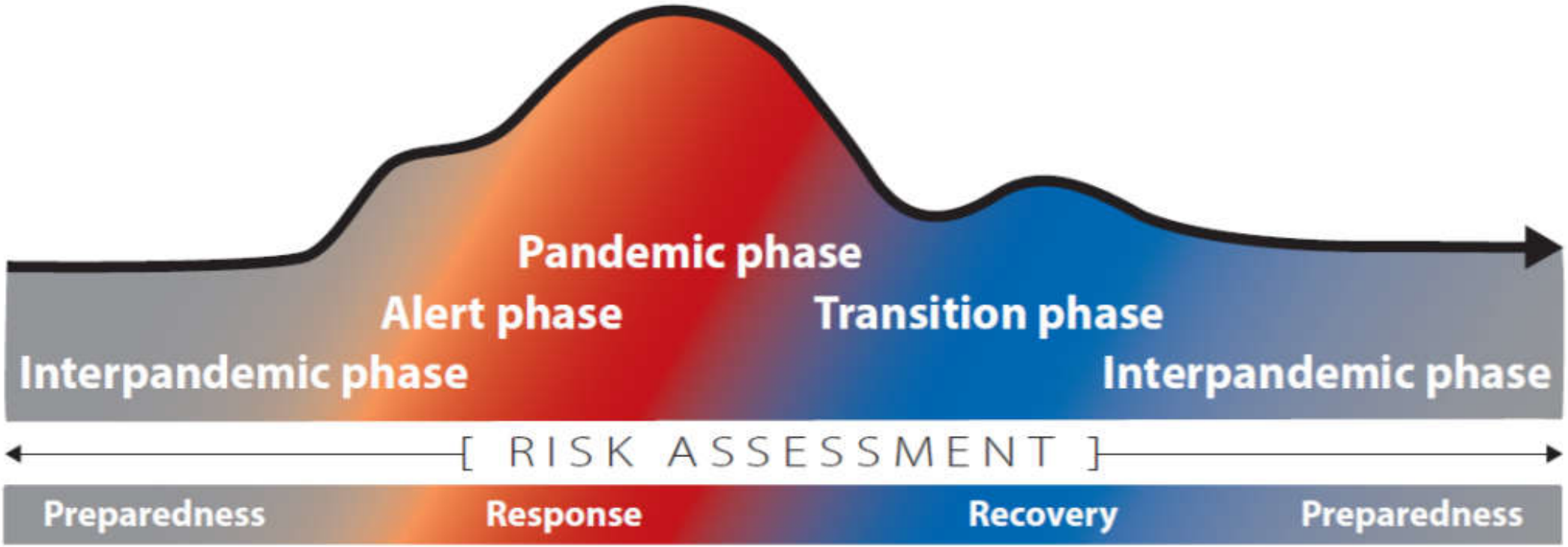
Contents

- Introduction
- Engineering principles
- Strategy for planning and preparedness
- Emergency management
- Conclusion

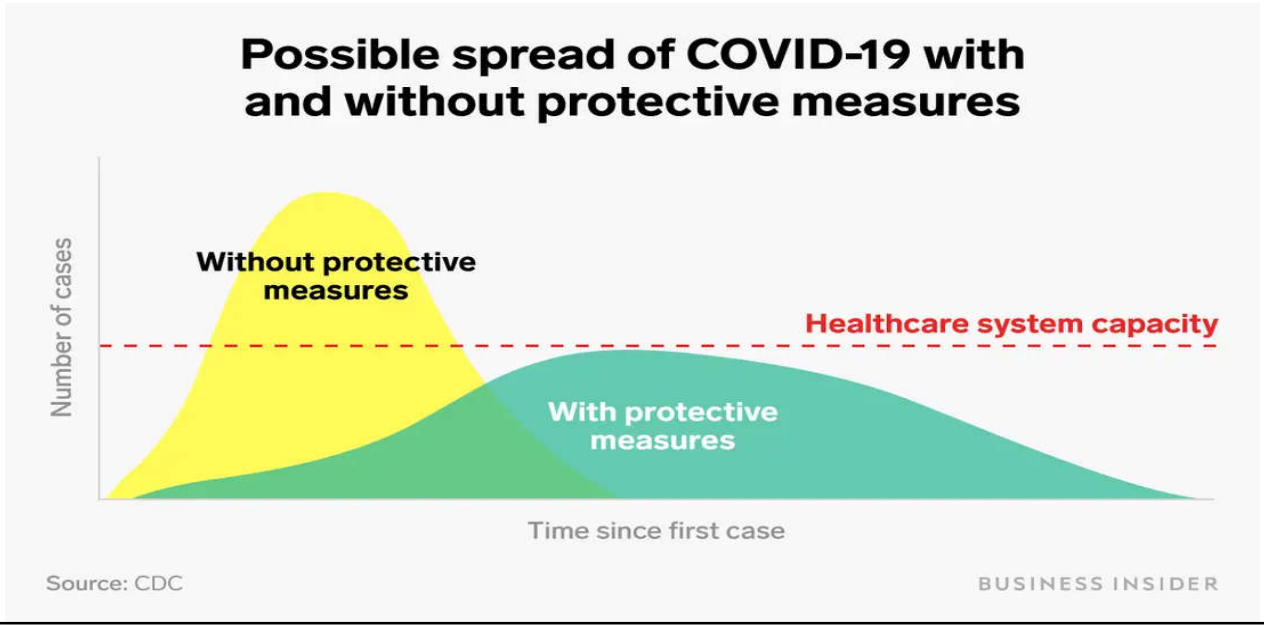
Introduction

- COVID-19 pandemic 2019冠状病毒病大流行
  - Public health crisis, significant social & economic impacts/consequences
  - The healthcare system is being tested as the pandemic develops
  - Health care facilities are crucial for tackling the epidemic and protecting the health care workers & vulnerable populations
  - Serious questions around capacity & risk
    - Not enough hospital beds, medical devices & protection

The continuum of pandemic phases



(Source: WHO's Pandemic Influenza Risk Management Guidance, https://www.who.int/influenza/preparedness/pandemic/influenza_risk_management/en/)



Flatten the curve of pandemics growth

Introduction

- Hospitals & healthcare systems 醫院和醫療系統
  - The healthcare systems in the world are trying to manage the COVID-19 pandemic
  - Health care facilities include hospital (acute care, psychiatric, rehabilitation), primary care outpatient facilities, ambulatory care facilities, small primary outpatient facilities, outpatient surgical facilities & assisted living facilities
  - Also nursing facilities, dental facilities & supporting facilities

- Ambulatory surgical centers
- Birth centers
- Blood banks
- Clinics and medical offices
- Diabetes education centers
- Dialysis Centers
- Hospice homes
- Hospitals
- Imaging & radiology centers
- Mental health & addiction treatment centers
- Nursing homes
- Orthopedic & other rehabilitation centers
- Telehealth
- Urgent care

(Source: https://www.rasmussen.edu/degrees/health-sciences/blog/types-of-healthcare-facilities/)

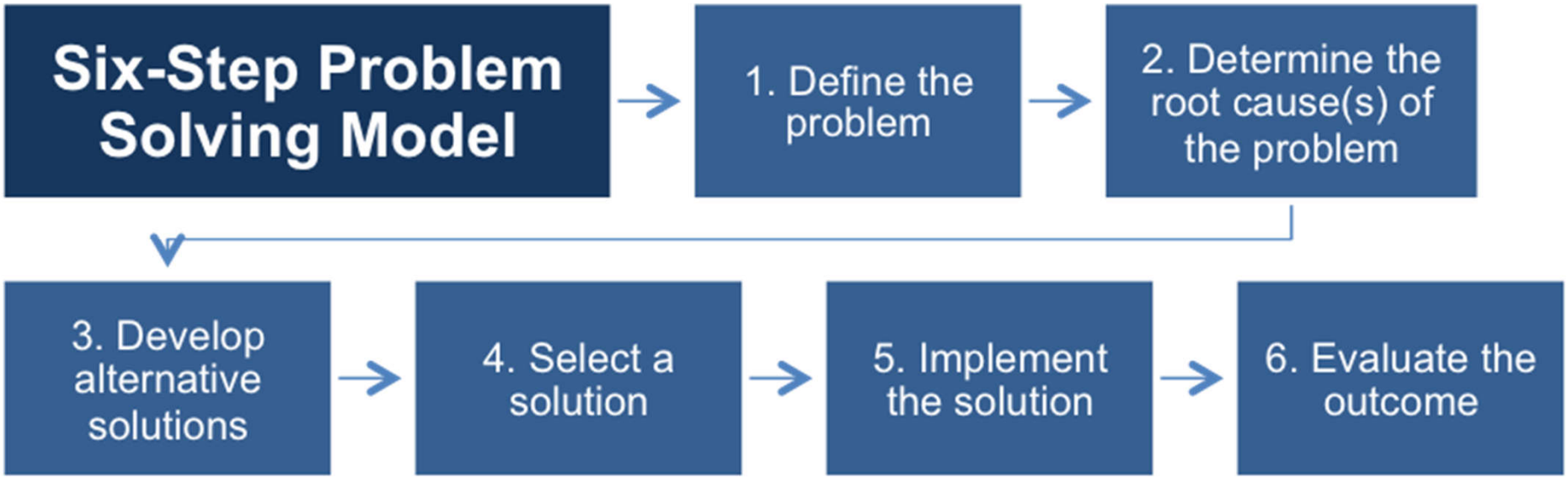
Introduction

- Three main types of health care facilities:
  - 1. Hospital facilities 醫院設施
  - 2. Outpatient health care facilities 門診醫療設施
  - 3. Residential health care & support facilities 住院醫療和支援設施
- Hospitals are complex large-scale sociotechnical systems involving a large diversity of professions: hospital management, clinical management, equipment & buildings

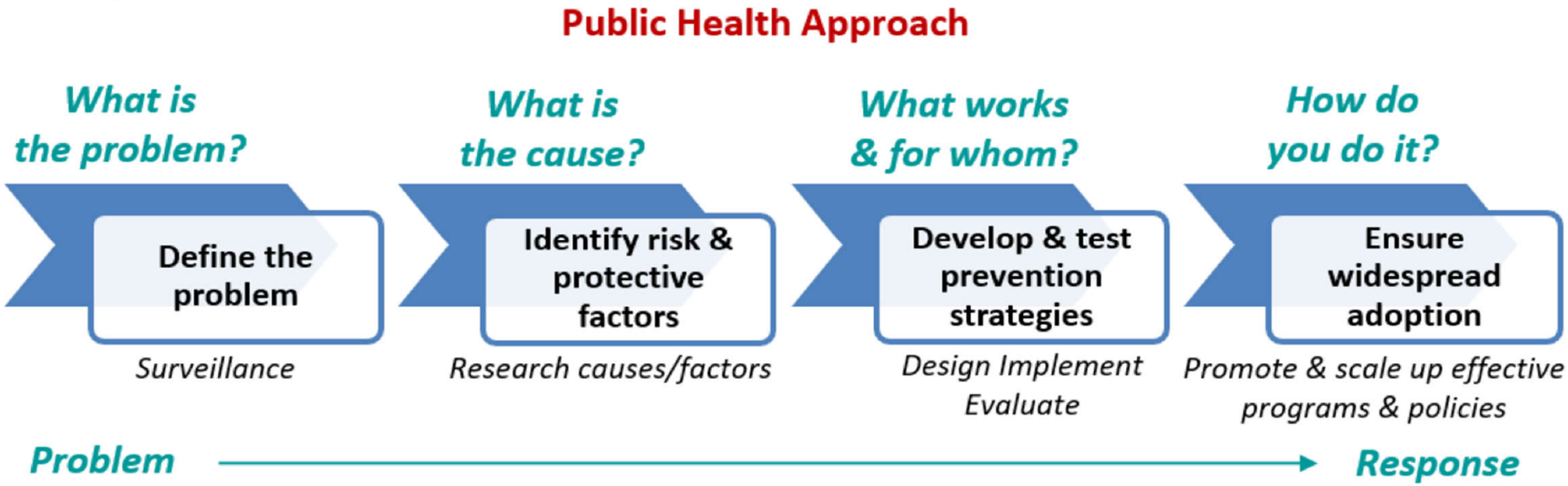
Introduction

- Healthcare & hospital engineering 醫療保健和醫院工程
  - Fight against infection control in the health care facilities, with support from Architecture & Engineering
  - How to increase the capacity to absorb & effectively manage the surge of COVID-19 patients and maintain other health service
  - Apply engineering approach for problem solving

Engineering approach for problem solving for public health



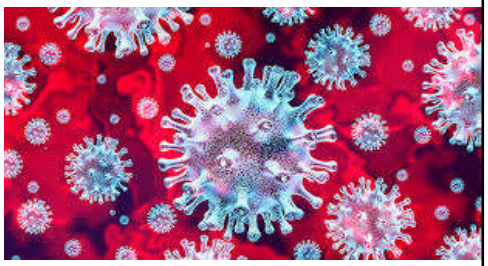
(Source: http://www.free-management-ebooks.com/news/six-step-problem-solving-model/)



(Source: https://www.nasbla.org/advocacy/public-health)

Introduction

- Identify the key problems of COVID-19
  - Situations many have never encountered (unprecedented crisis)

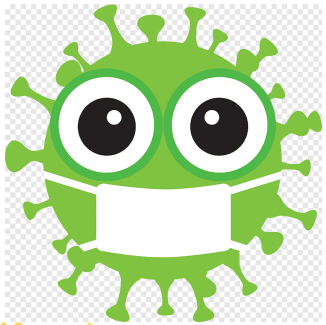


  - "*Invisible enemies*": difficult to trace the virus transmission source & infected persons (e.g. asymptomatic 無症狀的 & pre-symptomatic)
  - No available treatment or vaccination yet
  - Surge of infection & impact on health care service
    - Risk to vulnerable populations & healthcare workers

Introduction

- Engineering systems approach 工程系統方法
  - Use engineering knowledge to support the health care workers & the community
  - Establish & implement a systematic process
  - Main objective: safety of patients, health care workers & visitors
  - Help reduce the load & strain on the frontline health care workers & healthcare system
  - Support/Protect nurses & healthcare teams

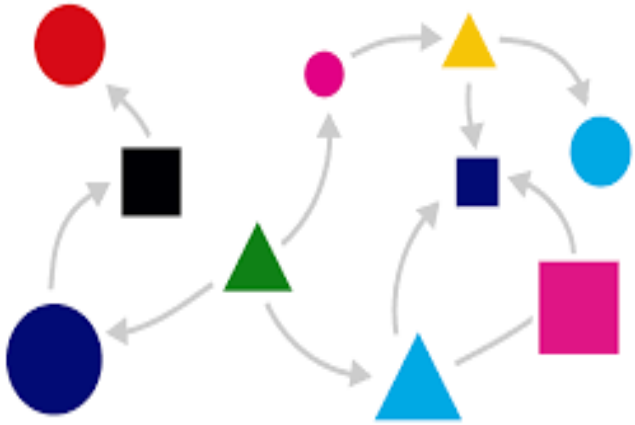
Introduction



- Criteria for measurement of performance:
  - Technical performance, including infection control, comfort, patient outcome
  - Safety, including fire prevention & control and minimizing falls & injuries for employees, visitors, and patients
  - Reliability & minimizing lost revenue
  - Minimizing maintenance costs
  - Minimizing energy costs
  - Adaptability

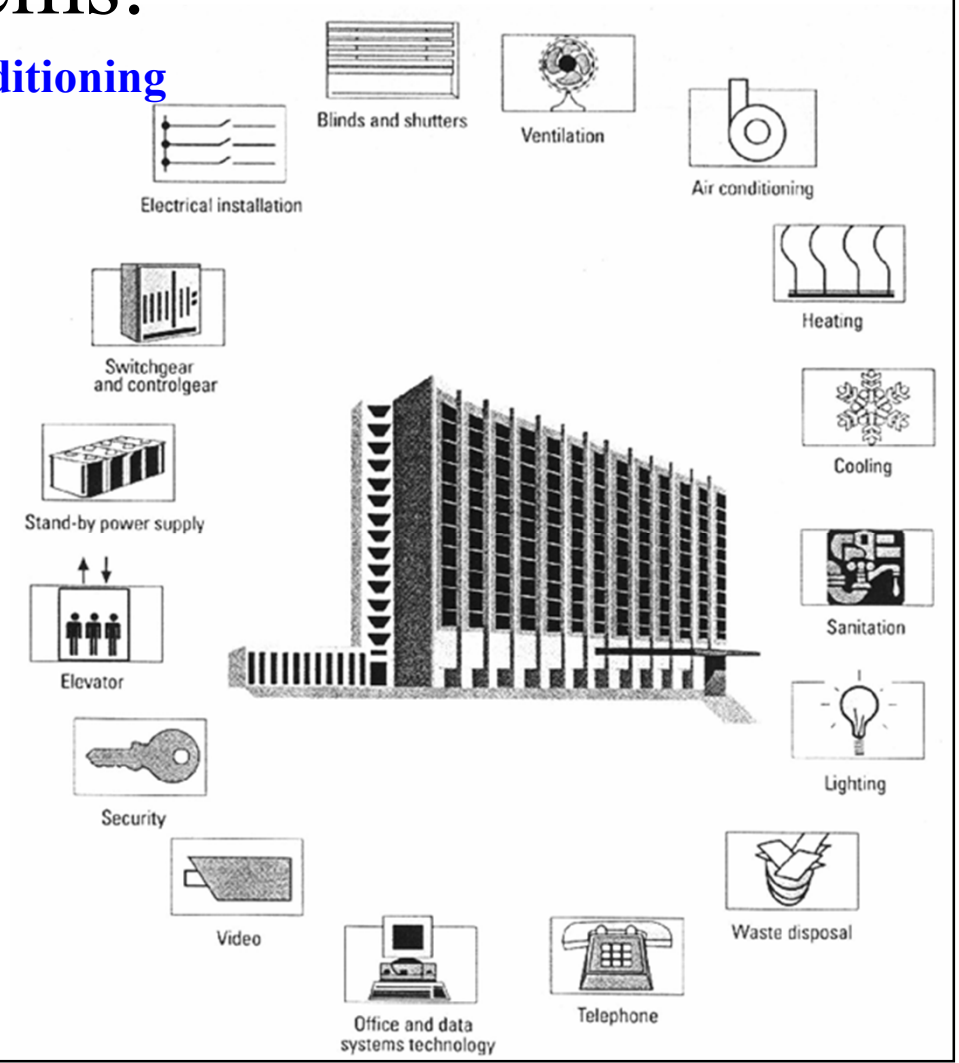
Engineering principles

- An Engineers' system philosophy
  - Systems thinking is applied to the analysis
  - Systems consist of sources and distribution
- Living entities that are:
  - Conceived (design)
  - Born (construction)
  - Assessed (commissioning Cx)
  - Nurtured (operation and maintenance O&M)



Engineering principles

- Typical engineering systems:
  - **HVAC - Heating, Ventilating and Air Conditioning**
  - IC - Instrumentation & Controls
  - BAS – Building Automation
  - F/G - Fuel Oil/Natural Gas
  - LS - Life Safety
  - G/V - Gas/Vacuum
  - P - Plumbing
  - SW - Special Water
  - NP - Normal Power
  - EP - Essential Power
  - LTG - Lighting
  - FAS - Fire Alarm
  - IT - Information Technology
  - FP - Fire Protection



Infection prevention and control (IPC) in health care facilities

PREVENT INFECTIONS
SAVE LIVES IN HEALTH CARE

HANDLE ANTIBIOTICS WITH CARE

WHAT'S THE PROBLEM?

- **1 IN 10 PATIENTS** get an infection while receiving care
- **UP TO 32% OF SURGICAL PATIENTS** get a post-op infection, up to 51% antibiotic resistant
- **UP TO 90% OF HEALTH CARE WORKERS** do not clean their hands in some facilities
- **INFECTIONS CAUSE UP TO 56% OF DEATHS** among hospital-born babies
- **UP TO 20% OF AFRICAN WOMEN** get a wound infection after a caesarean section
- **50-70% OF INJECTIONS** given in some developing countries are unsafe
- **INFECTIONS** can lead to disability, **ANTIBIOTIC RESISTANCE**, increased hospital time and death

World Health Organization

PREVENT INFECTIONS
SAVE LIVES IN HEALTH CARE

HANDLE ANTIBIOTICS WITH CARE

WHAT'S THE SOLUTION?

- **HAVE ACTIVE INFECTION PREVENTION AND CONTROL PROGRAMMES** and target antibiotic resistance
- **USE CLEAN PRACTICES** and asepsis for interventions
- **PRACTICE HAND HYGIENE** to prevent infections and reduce the spread of antibiotic resistance
- **HAVE ENOUGH STAFF**, a clean and hygienic environment and don't overcrowd health care facilities
- **MONITOR INFECTIONS** and make action plans to reduce their frequency
- **NEVER RE-USE** needles and syringes
- Only dispense antibiotics when **TRULY NEEDED** to **REDUCE THE RISK OF RESISTANCE**

World Health Organization

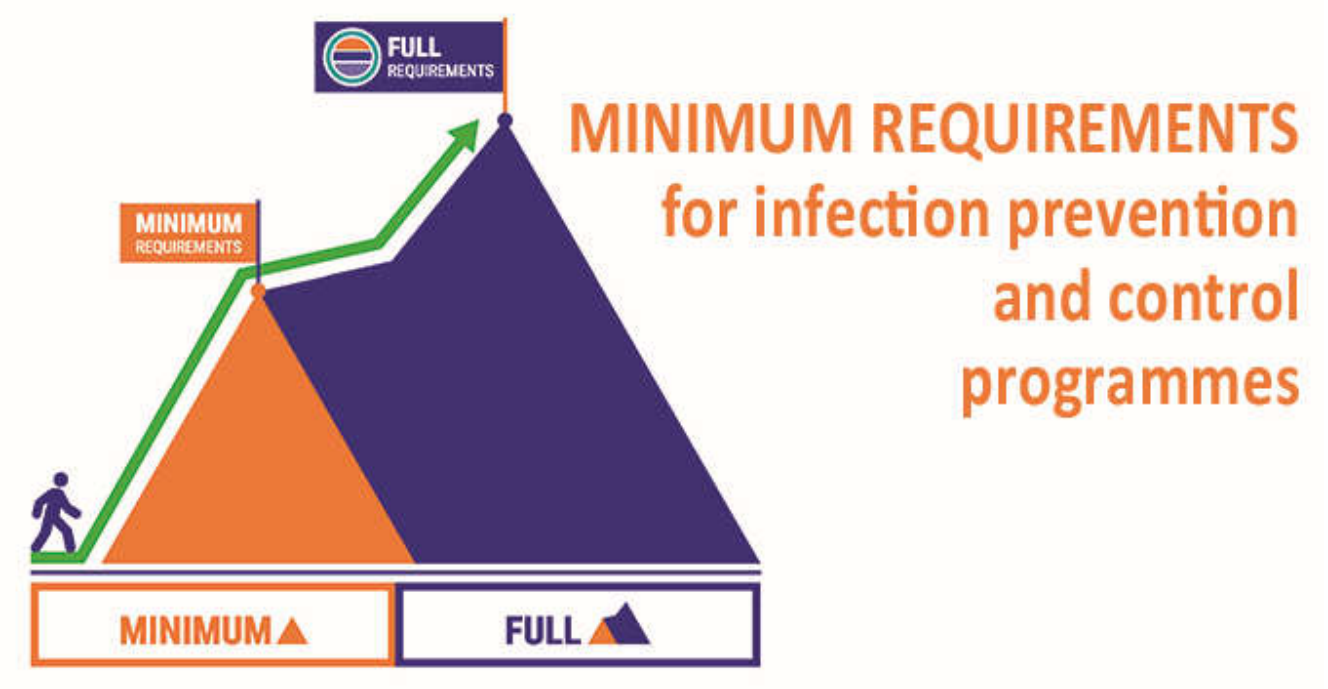


(Source: WHO Infection prevention and control (IPC) https://www.who.int/infection-prevention/)

Core components of infection prevention and control (IPC) programmes

1. IPC programmes 2. IPC guidelines 3. IPC education & training 4. Health care-associated infection surveillance	5. Multimodal strategies 6. Monitoring, evaluation & feedback 7. Workload, staffing & bed occupancy 8. Built environment, materials & equipment for IPC

World Health Organization

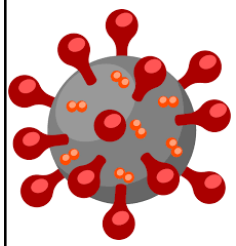


WHO Guidelines:

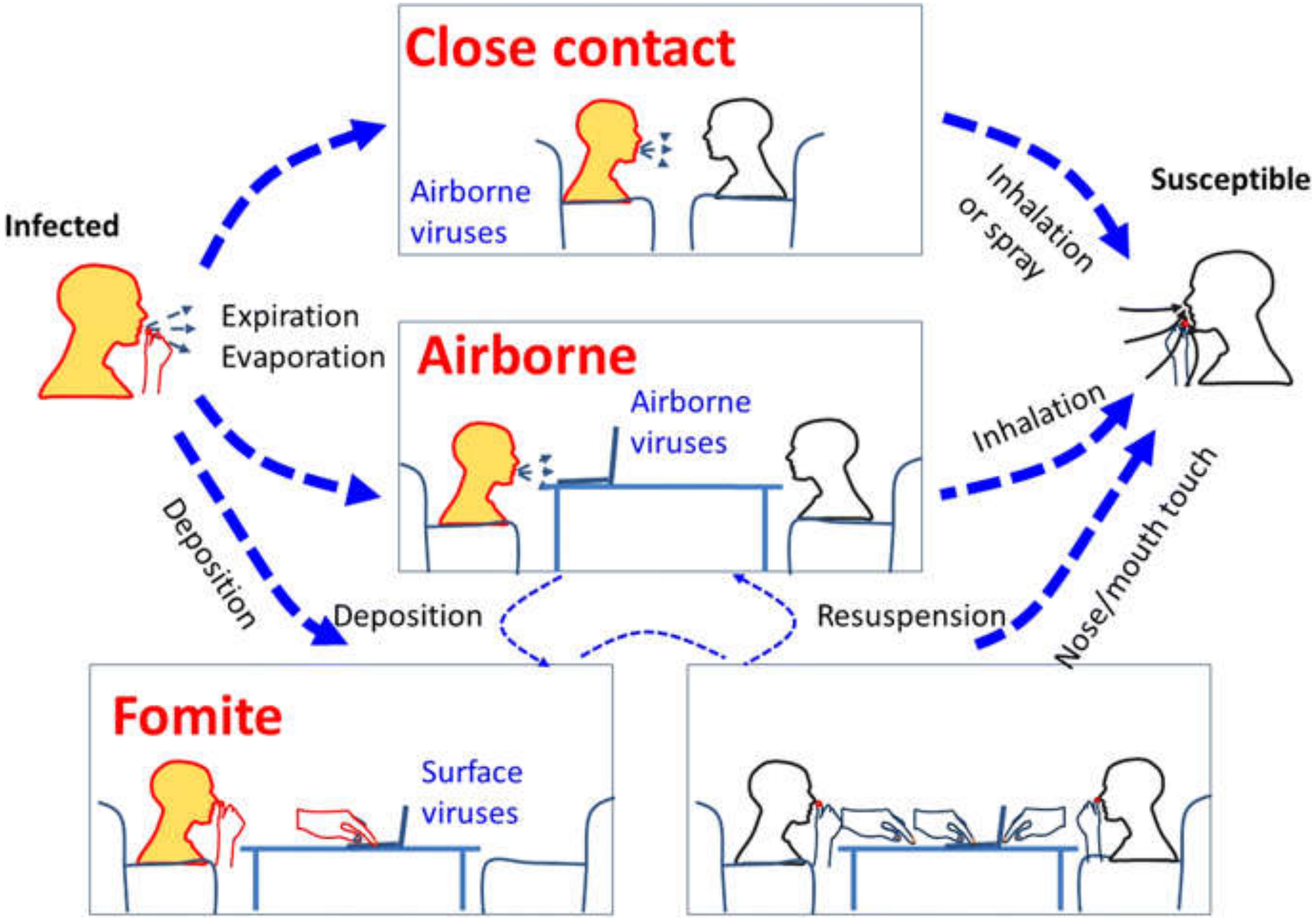
- Guidelines on core components of infection prevention and control programmes at the national and acute health care facility level https://www.who.int/gpsc/ipc-components-guidelines/
- Minimum requirements for infection prevention and control (IPC) programmes https://www.who.int/infection-prevention/publications/min-req-IPC-manual/
- Improving infection prevention and control at the health facility https://apps.who.int/iris/handle/10665/279788

Engineering principles

- COVID-19 modes of transmission:
  - 1. Droplets sprayed by affected individuals
  - 2. Contact with patient respiratory secretions
  - 3. Contaminated surfaces & equipment
- Infection control risk assessment (ICRA)
  - Symptoms & viral shedding to the environment varied considerably
  - Many commonly used items, toilet facilities, and air samples had evidence of viral contamination



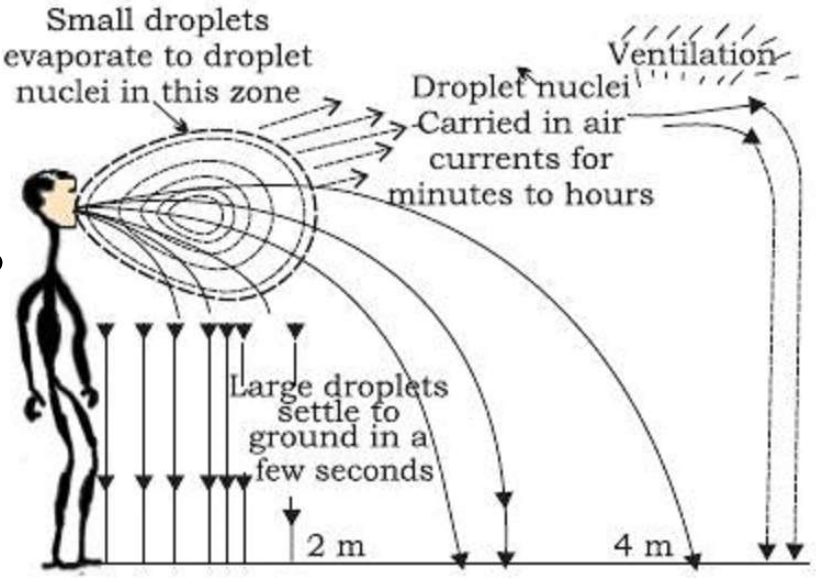
Possible transmission routes of respiratory infection



(Source: Recognition of aerosol transmission of infectious agents: a commentary https://bmcinfectdis.biomedcentral.com/articles/10.1186/s12879-019-3707-y)

Engineering principles

- Airborne vs contact transmission
  - Disease spread through both direct (droplet & person-to-person) as well as indirect contact (contaminated objects & airborne transmission)
- Basic science
  - Airborne microorganisms
  - Perspective of particle physics
  - Airborne transmissibility
  - Transmission dynamics



Infection prevention & control using environmental/engineering controls

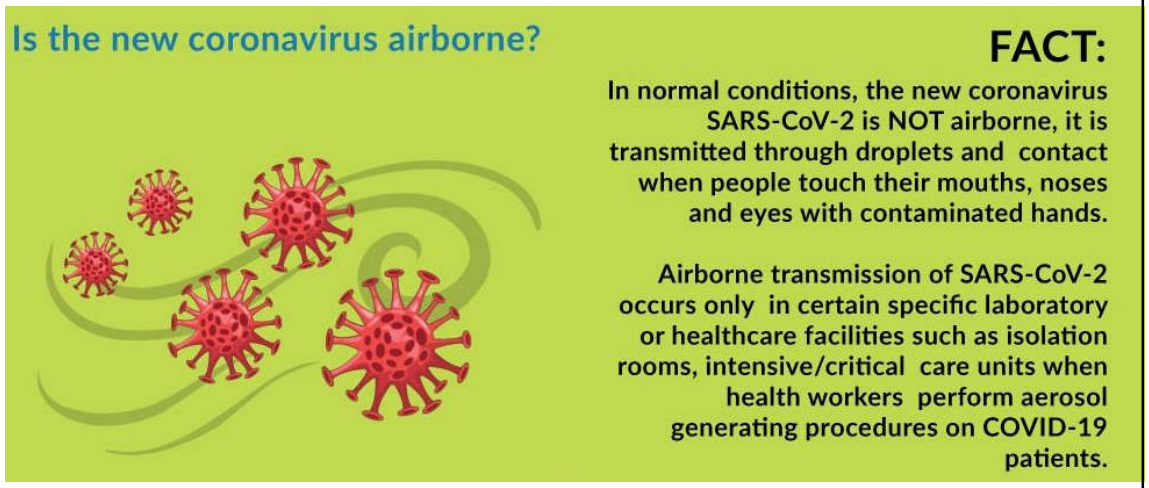
Design criteria:	**Control measures:**
- Infection sources	- Outdoor air ventilation
- Control measures	- Filtration
- Air quality	- Pressure differential
- Air movement	- Anterooms
- Temperature and humidity	- Contaminant source control
- Smoke control	- Temperature and humidity

- Fresh air, ventilation, and isolation are key factors in controlling the spread, all of which have connections to the built environment
- Main issues: filtration, air patterns, air changes, dilution, temperature, humidity, disinfection, and pressurization
- Design principle: "*Airflow from Clean to Less Clean*"

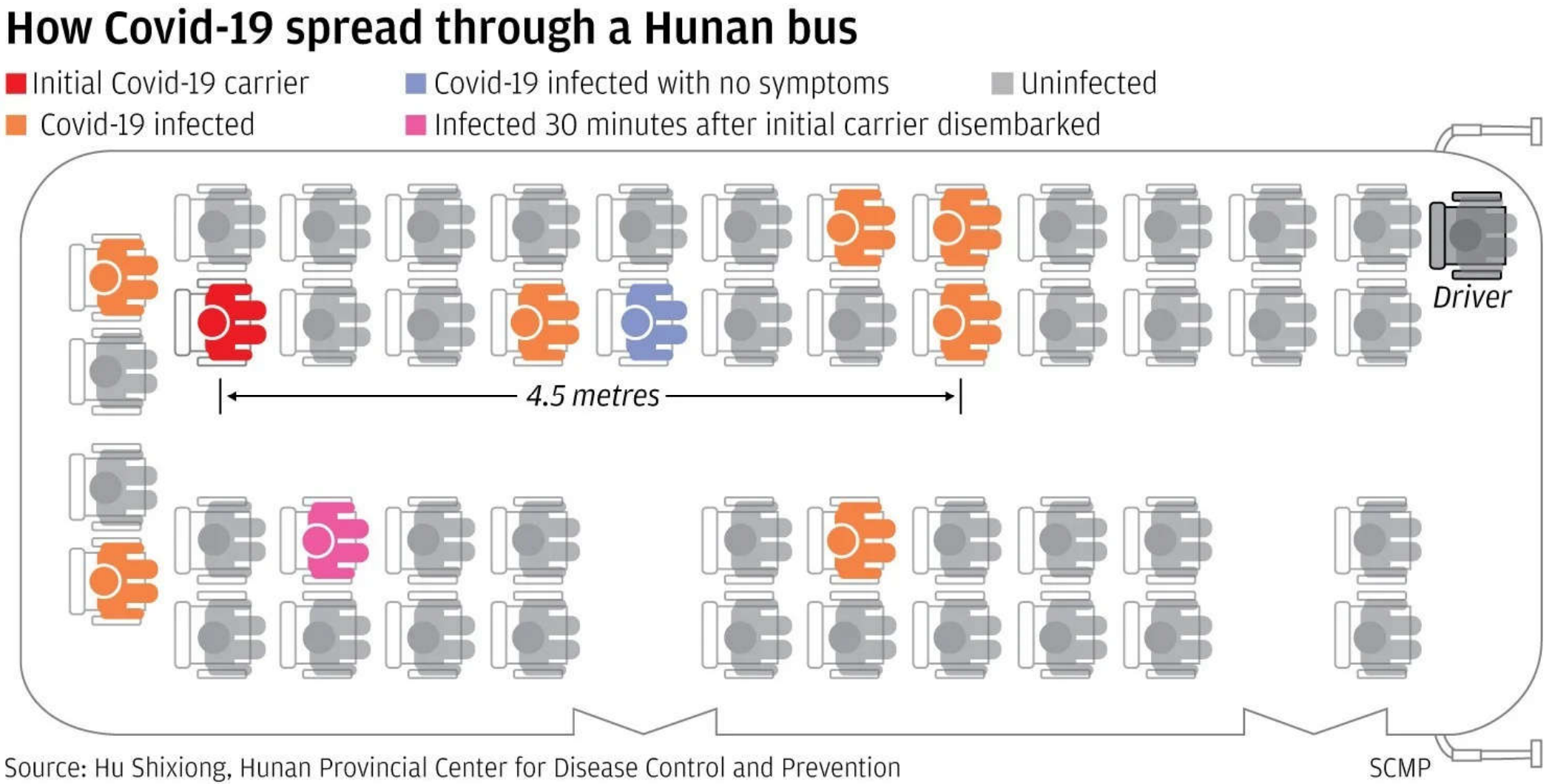
(Source: 2019 ASHRAE Handbook - HVAC Applications, Chapter 9 Health Care Facilities)

Engineering principles

- Prevention strategies for COVID-19:
  - Increase air changes
  - Outdoor air intakes
  - Exhaust air outlets
  - Air filters
  - Disinfection & decontamination
    - Using ultra-violet (UV) light, ionization & chemicals
  - COVID-19 can be transmitted through *aerosols* 氣溶膠
    - Movement & concentration of aerosols can be influenced by the HVAC system

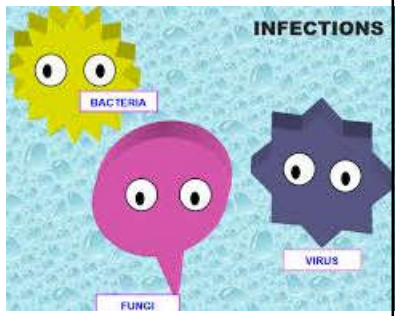


COVID-19 spread through a bus in Hunan, China



(Source: https://www.scmp.com/news/china/science/article/3074351/coronavirus-can-travel-twice-far-official-safe-distance-and-stay)

Engineering principles



- Hospital-Associated Infections (HAI)
  - Nosocomial infections 醫療照顧相關感染
  - How to maintain clean & hygienic environment

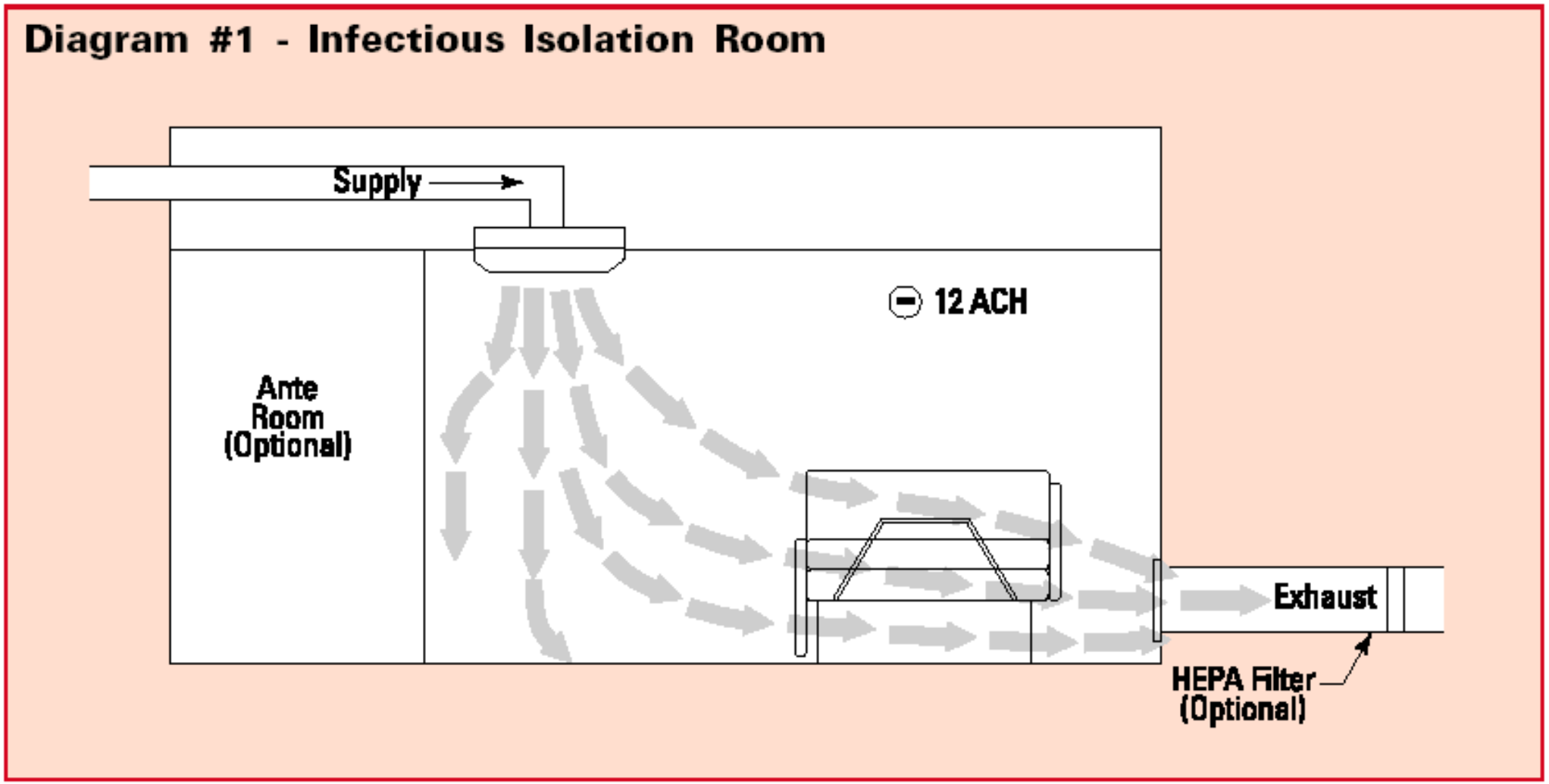
- Delimitation of the space in critical, semi-critical & non-critical area
- Physical barriers erected between areas
- Air contamination control & proper workflow

- Correct choice of finishing materials
- Design of isolation rooms, operating rooms, emergency depts & sterile processing

Engineering principles

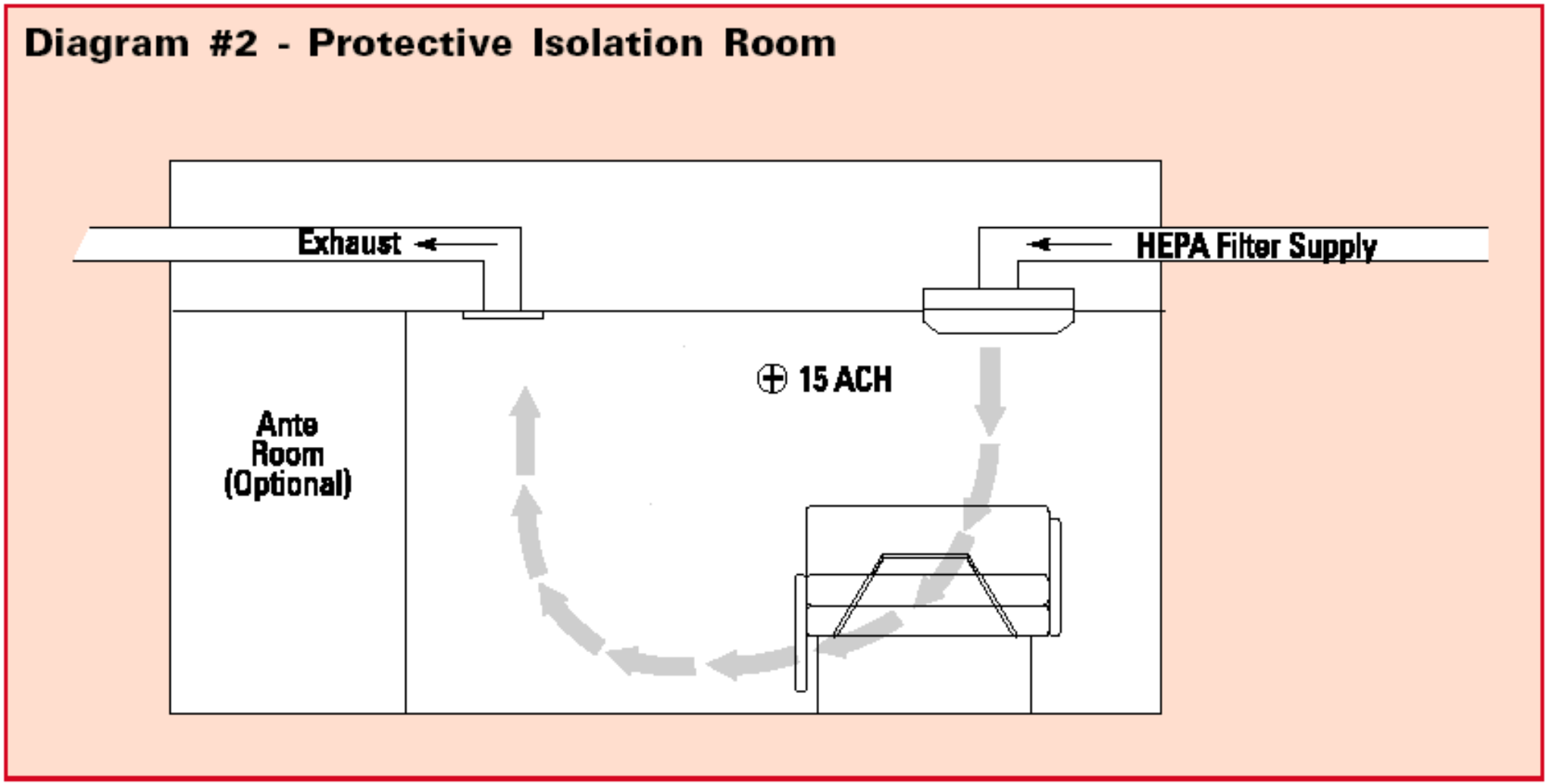
- Types of isolation rooms:
  - Airborne infection isolation (AII) room (for patients having an airborne communicable disease)
  - Protective environment (PE) room (for patients with weakened immune system)
  - Combined AII/PE (for patients suffering from a weakened immune system who also have an airborne communicable disease)
  - Contact isolation (for patients having a communicable disease that is not airborne)

Infectious isolation room



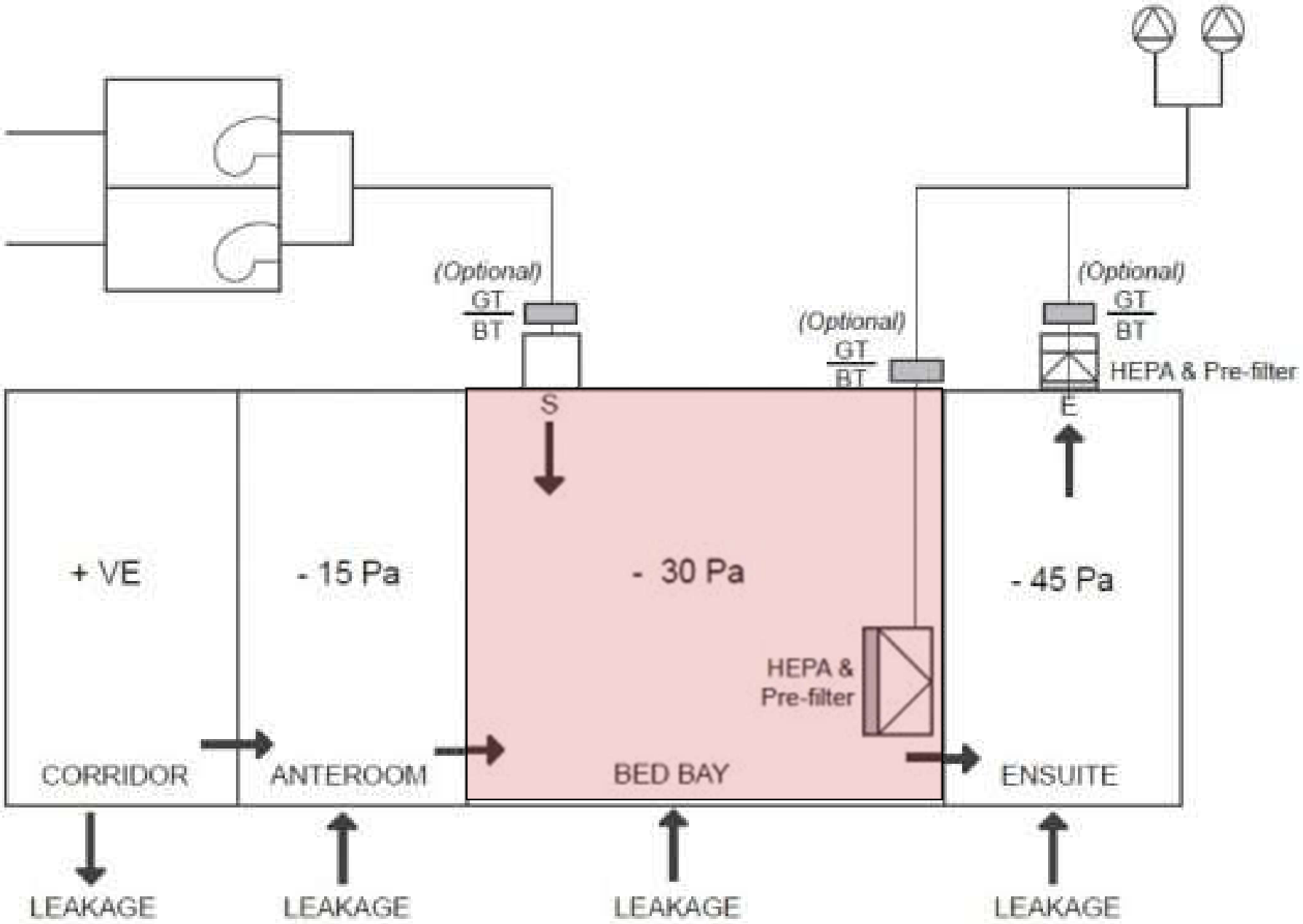
(Source: Source: http://www.price-hvac.com)

Protective isolation room



(Source: Source: http://www.price-hvac.com)

Schematic of isolation room with terminal mounted HEPA filters (pressure balanced)



(Source: Design Considerations for Hospital Class-N Isolation Rooms https://www.airepure.com.au/design-considerations-hospital-class-n-isolation-rooms/)

Engineering principles

- Two important concepts:
  - **Contamination control 污染控制**

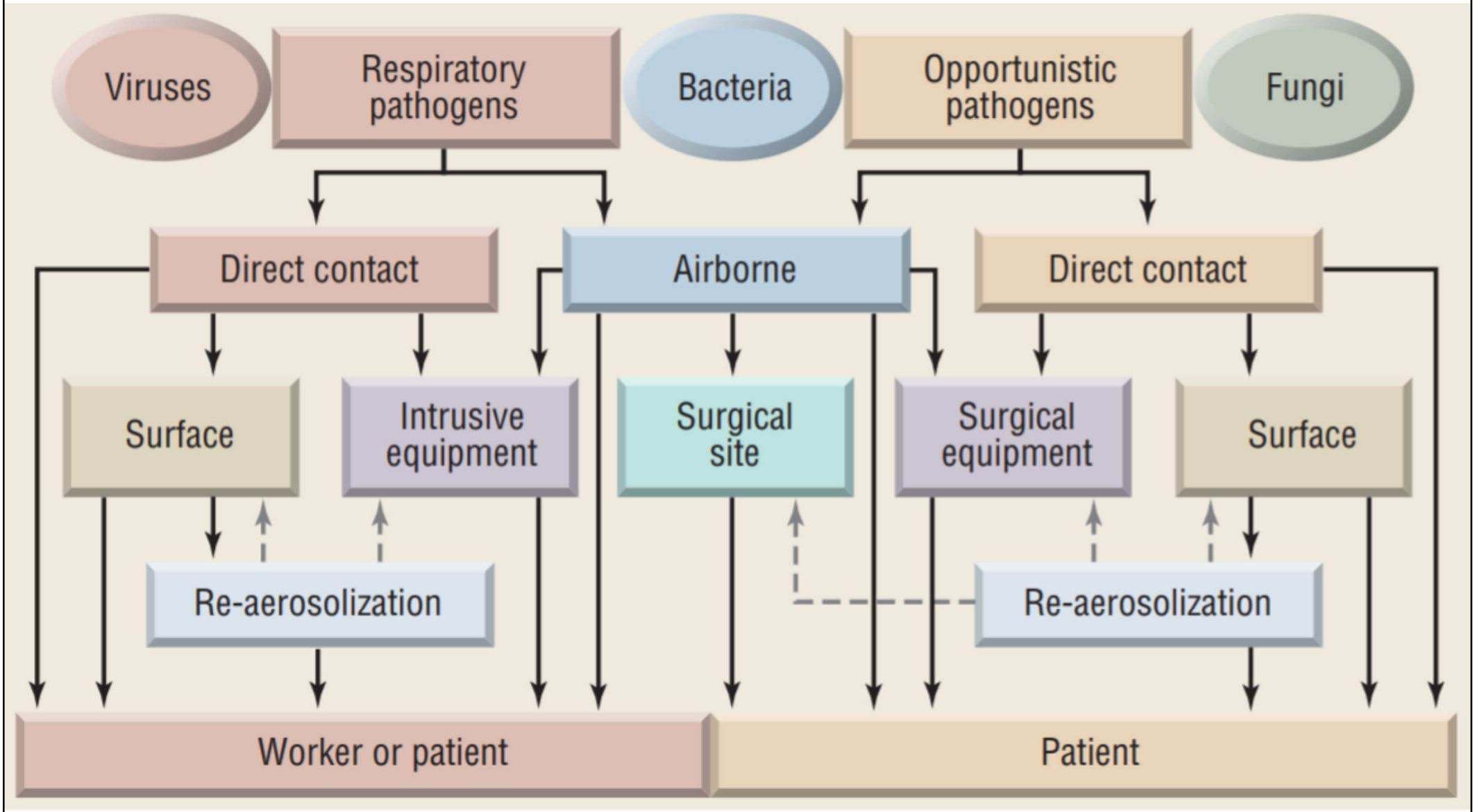
HVAC is dominant

    - Control the existence, growth & proliferation of contamination in certain areas (e.g. cleanrooms)
    - Achieve asepsis (無菌的) environment -- being free from particulates, particularly bacteria, viruses & fungi
  - **Infection Control 感染控制**

HVAC is secondary

    - Prevent the spread of infections in healthcare settings
    - Infection equation: the probability of getting an infection
    - *Infection = (Dose x Site x Virulence x Time)/(Level of host defense)*

Major aerobiological pathways of airborne nosocomial pathogens

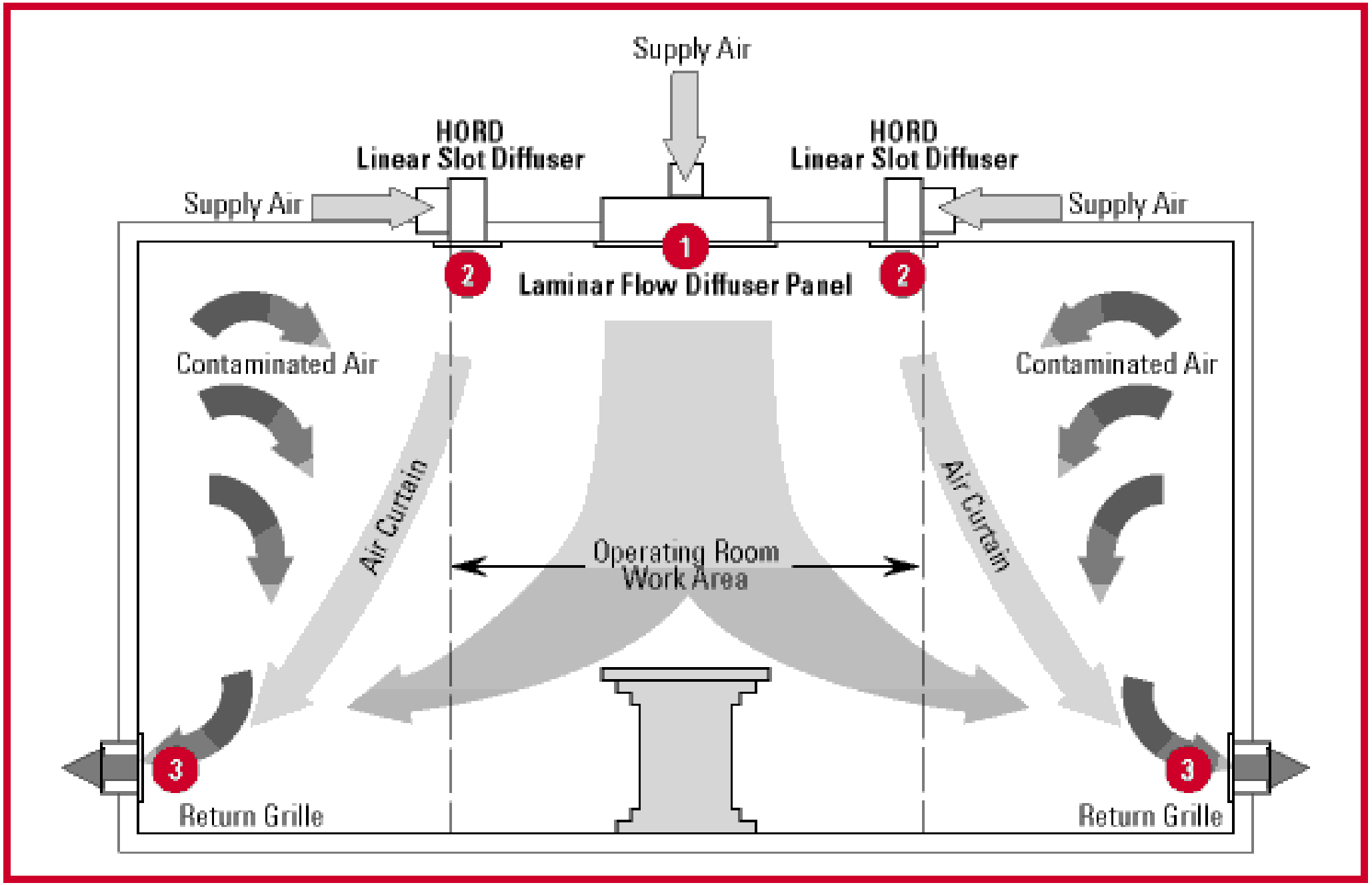


(Source: Kowalski, W., 2007. Air-treatment systems for controlling hospital-acquired infections, *HPAC*, 79 (1): 2-22)

Hospital operating theatre (typical design)

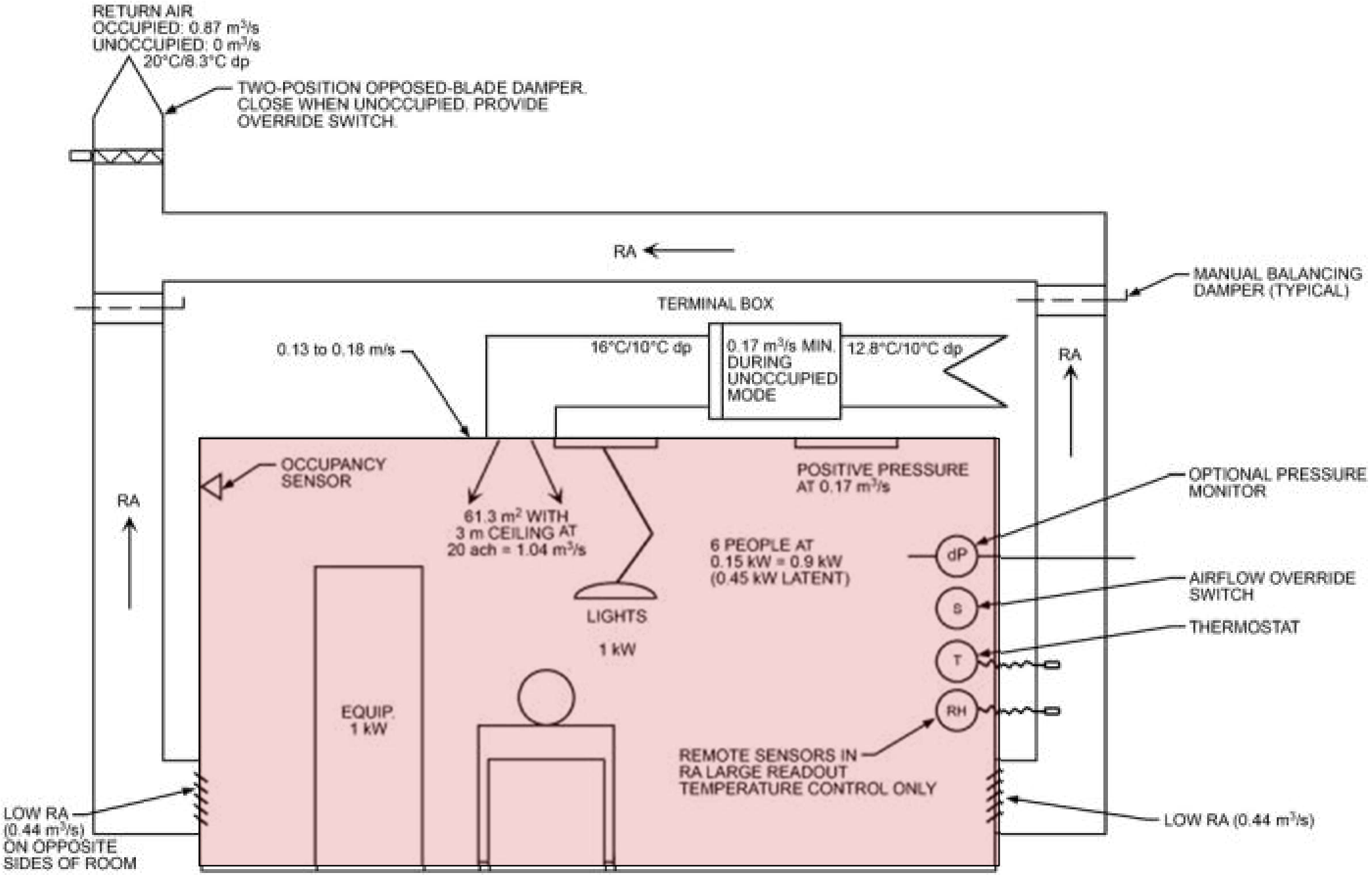
(Source: Source: http://www.price-hvac.com)

Hospital operating theatre (laminar flow with air curtains)



(Source: Source: http://www.price-hvac.com)

Operating room layout



(Source: ASHRAE, 2019. *ASHRAE Handbook 2019 HVAC Applications*, Chapter 9 Healthcare Facilities.)

Engineering principles

- HVAC systems can protect healthcare workers & enhance confidence by providing safe environment for their interactions with most contagious patients & reduce exposure when patients discharge contaminants during procedures
- For example, airborne infection isolation (AII) rooms require 12 air changes, negative relative pressure & air exhausted directly

(Reference: COVID 19 Guidance by Michael Sheerin https://www.bdcnetwork.com/tlccovid-19ventilationguidance)

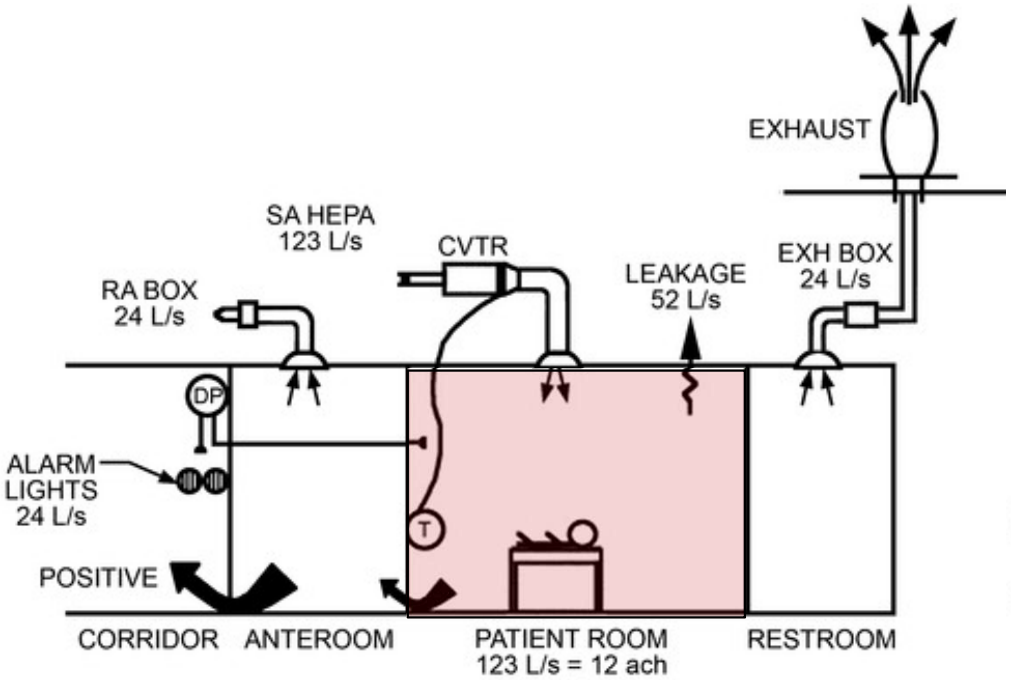
Engineering principles

- Typical HVAC components:
  - Air terminals (e.g. ceiling diffuser)
  - Filtration system (e.g. MERV [minimum efficiency reporting value], and HEPA [High-efficiency particulate] air filters 高效濾網)
  - Exhaust system (for air discharge)
  - Monitoring device (for differential air pressure)
  - Ante room requirements (airlock lobby, with two doors)

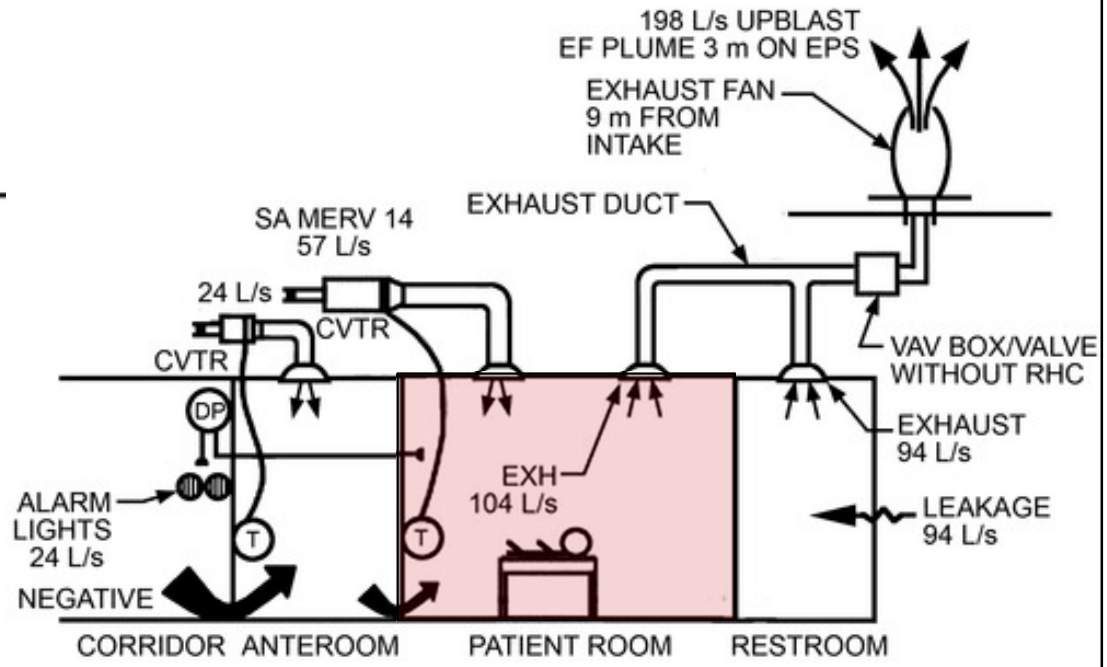
Engineering principles

- ASHRAE/ASHE Standard 170 - Ventilation of Health Care Facilities
  - Ventilation system design requirements that provide environmental control for comfort, asepsis, and odour in health care facilities
    - Such as operating room (OR), patient care area, procedure room, protective environment (PE) room, airborne infection isolation (AII) room

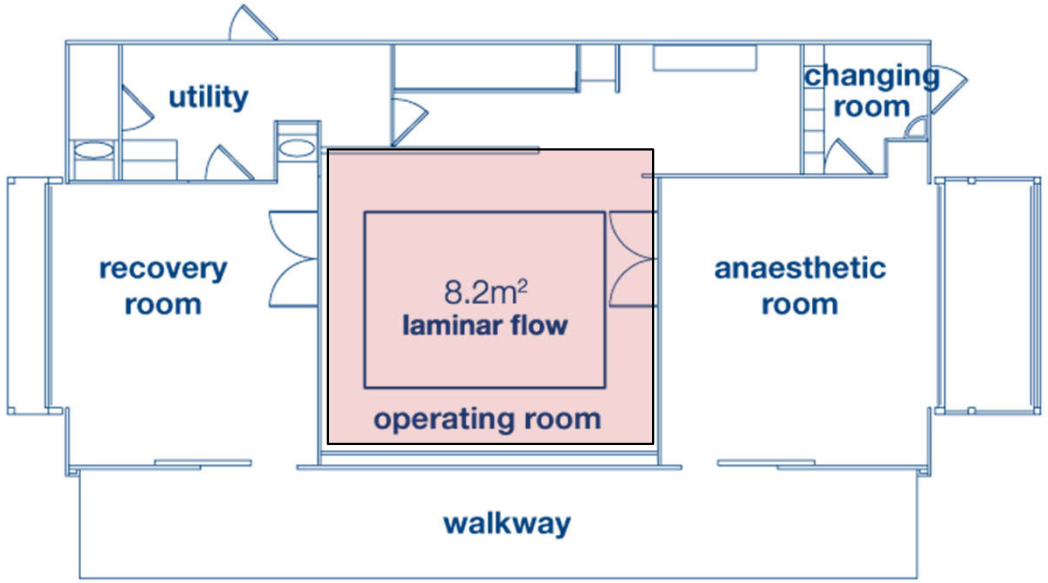
Operating room layout and arrangements



Protective environment room arrangement



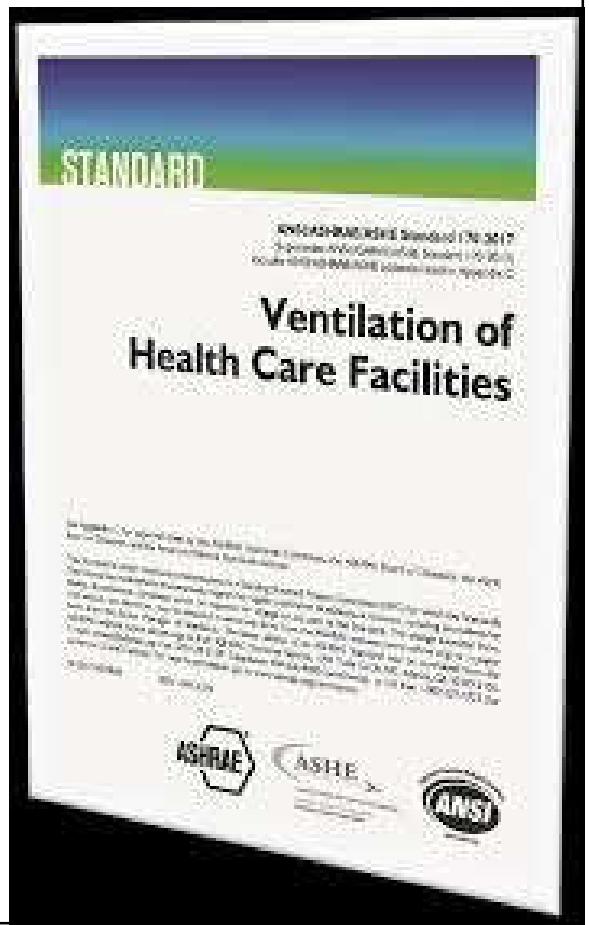
Airborne infection isolation room



(Source: ASHRAE, 2019. *ASHRAE Handbook 2019 HVAC Applications*, Chapter 9 Healthcare Facilities.)

Engineering principles

- Systems and equipment:
  - Utilities (electrical power, heating & cooling sources)
  - Air handling unit (AHU) design
  - Outdoor air intakes & exhaust discharges
  - Filtration
  - Heating & cooling systems
  - Humidifiers
  - Air distribution
  - Energy recovery systems
  - Insulation & duct lining



Engineering principles

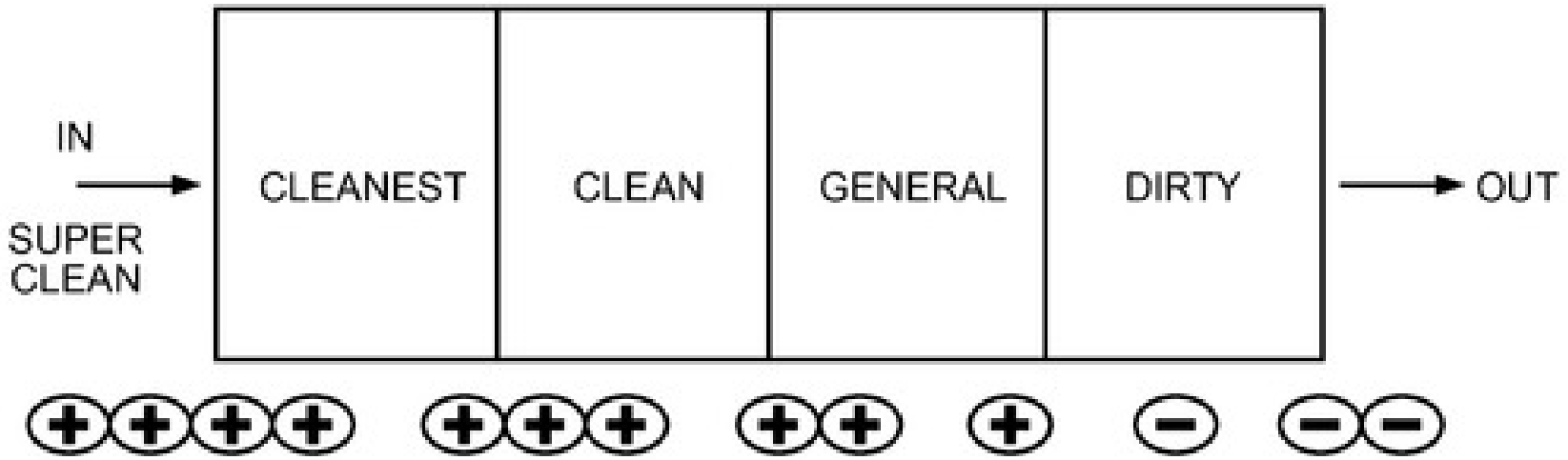
- Space ventilation (room specific requirements)
  - For hospital spaces, outpatient spaces & nursing home spaces
  - Controversial issues regarding HVAC & infection control e.g. air change rates & levels of filtration
  - How to pressurize to move air from clean to less clean areas
  - Maintain & control room pressurization
  - Maintain proper temperature & humidity

Table 1 Sample of ASHRAE *Standard* 170 Design Parameters

Function of Space	Pressure Relationship to Adjacent Areas	Minimum Outdoor ach[*]	Minimum Total ach[*]	All Room Air Exhausted Directly to Outdoors	Air Recirculated by Room Units	Design Relative Humidity,%	Design Temp. °C
Operating room	Positive	4	20	NR[*]	No	20 to 60	20 to 24
Emergency department public waiting area	Negative	2	12	Yes	NR[*]	max. 65	21 to 24
AII rooms	Negative	2	12	Yes	No	max. 60	21 to 24
Patient room	NR[*]	2	4	NR[*]	NR[*]	max. 60	21 to 24

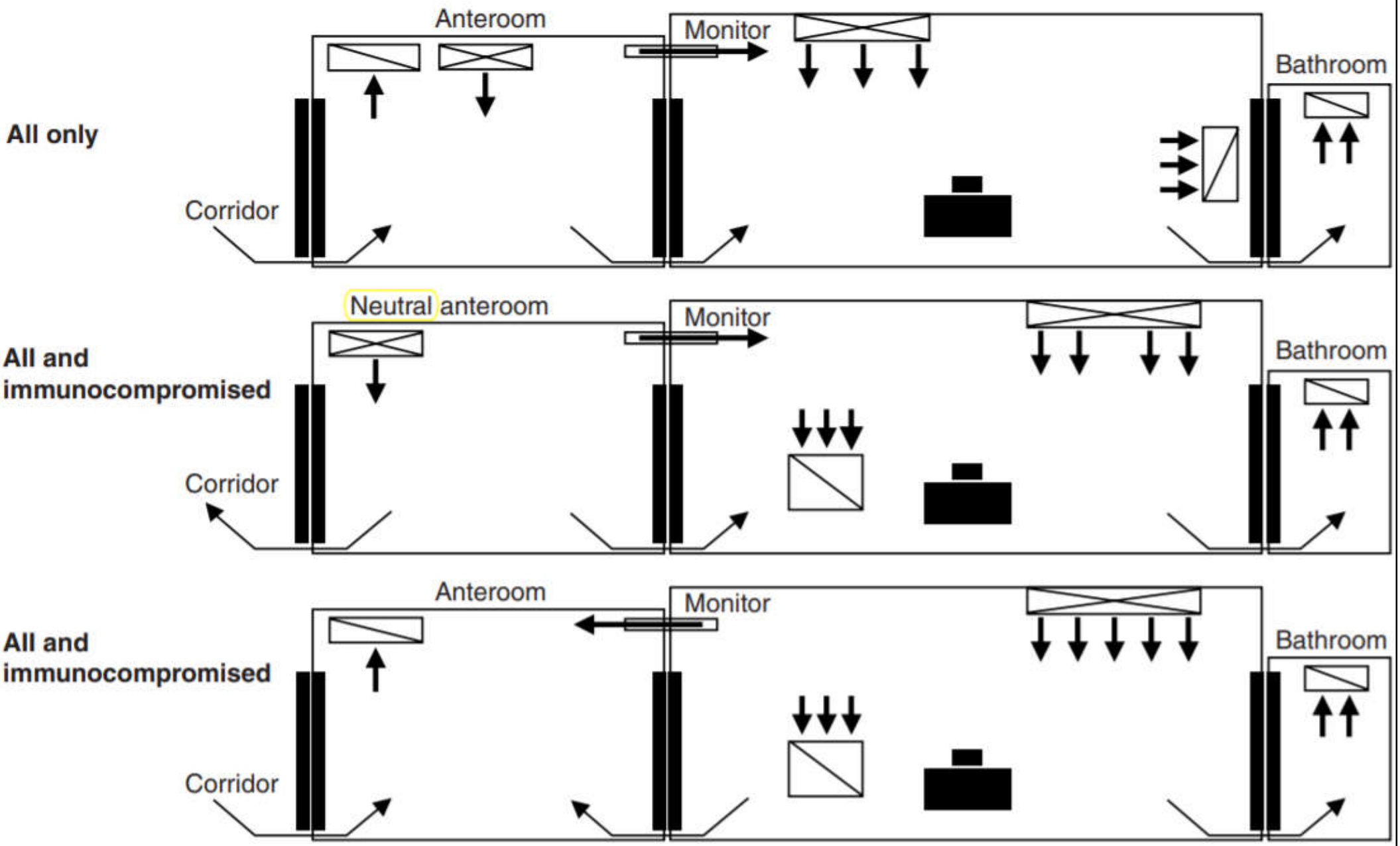
[*] ach = air changes per hour, NR = no requirement.

Controlling air movement through pressurization



(Source: ASHRAE, 2019. *ASHRAE Handbook 2019 HVAC Applications*, Chapter 9 Healthcare Facilities.)

Example of airborne infection isolation (AII) room with anteroom and neutral anteroom



(Source: CDC Guidelines for Environmental Infection Control in Health-Care Facilities http://www.cdc.gov/infectioncontrol/pdf/guidelines/environmental-guidelines-P.pdf)

Design standards for airborne infectious isolation rooms (AIIR)

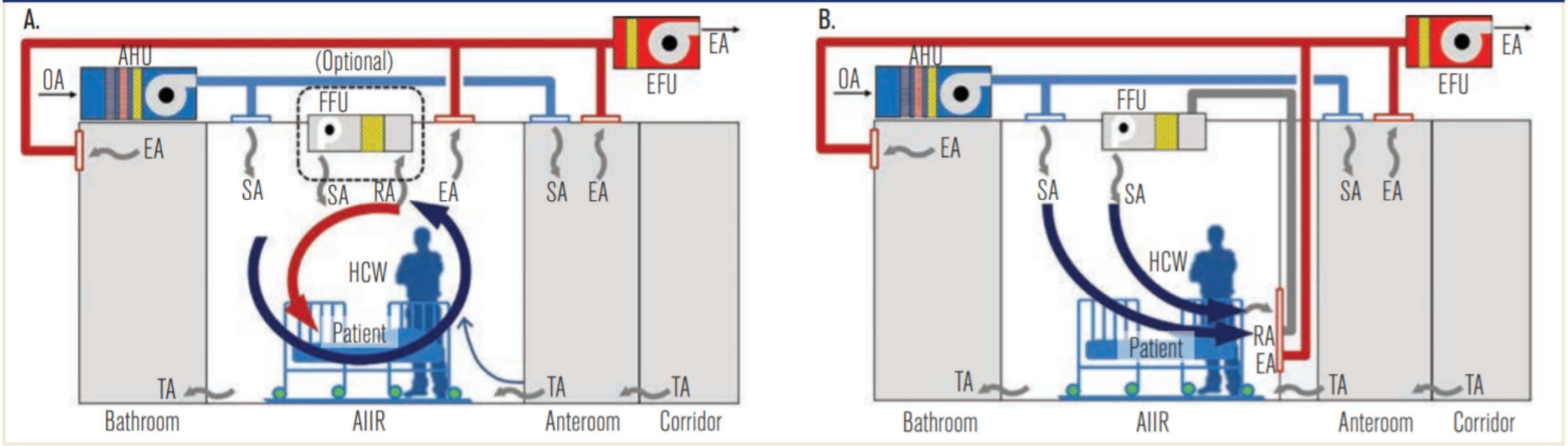
TABLE 1 Design standards for AIIR to prevent airborne contamination.[11]

	ORGANIZATION	AIR CHANGE RATE (ACH)		PRESSURE DIFFERENTIAL	RECIRCULATION	ANTEROOM
USA	Centers for Disease Control and Prevention	Existing: More than 6	New/Remodeling: More than 12	More than 2.5 Pa	Yes (w/HEPA Filter)	Recommend
Canada	Public Health Agency of Canada	Existing: More than 6	New/Remodeling: More than 9	–	Yes (w/HEPA Filter)	Recommend
UK	Department of Health	More than 10		More than 5 Pa	No	Recommend
Norway	Folkenhelseinstitutt	More than 12		More than 5 Pa	No	Mandatory
Australia	Department of Health And Human Services	Mandatory: More than 12	Recommend: More than 15	More than 15 Pa	No	Mandatory
Hong Kong	Infection Control Committee Department of Health	Existing: More than 6	New/Remodeling: More than 12	More than 2.5 Pa	Yes (w/HEPA Filter)	–
South Korea	Centers for Disease Control and Prevention	Mandatory: More than 6	Recommend: More than 12	More than 2.5 Pa	Yes (w/HEPA Filter)	Mandatory

(Source: Cho, J, Woo, K. and Kim, B.S., 2019. Improved ventilation system for removal of airborne contamination in airborne infectious isolation rooms, *ASHRAE Journal*, 61 (2): 8-21. https://images.magnetmail.net/images/clients/ASHRAE/attach/AJ_Newsletter/Cho_February_2019.pdf)

Ventilation strategies for airborne infectious isolation rooms (AIIR)

FIGURE 1 Ventilation strategies of the AIIR; (a) typical ventilation system and (b) improved ventilation system.



A. Typical ventilation system	**B. Improved ventilation system**
It may not efficiently reduce the pollutant concentrations of an infectious source at specific locations due to air mixing in the AIIR.	To have exhaust air (EA) grilles on the wall near the floor at the head of the bed, and to have supply air (SA) diffusers at the ceiling above the foot of the bed.

(Source: Cho, J, Woo, K. and Kim, B.S., 2019. Improved ventilation system for removal of airborne contamination in airborne infectious isolation rooms, *ASHRAE Journal*, 61 (2): 8-21. https://images.magnetmail.net/images/clients/ASHRAE/attach/AJ_Newsletter/Cho_February_2019.pdf)

Strategy for planning and preparedness

- Planning of health service & health facilities:
  - To better use the current facilities & develop new (emergency) facilities
  - Achieve reliable & effective health care delivery
    - Work with clinicians & medical professionals
    - Coordinate operations & identify needs/priorities
    - Define key areas & designated rooms
- Three critical issues to consider:
  - Healthcare system planning, infection control & emergency response

Strategy for planning and preparedness

- **COVID-19 Healthcare Planning Checklist**

  [From U.S. Department of Health and Human Services (HHS) Office of the Assistant Secretary for Preparedness and Response (ASPR)]

  - 1. Demand & operations planning
    - Implement more real-time tracking tools to continuously assess demand levels & better predict surges
  - 2. Talent management (human resources)
  - 3. Patient flow (operational procedures)
  - 4. Scheduling (logistics)

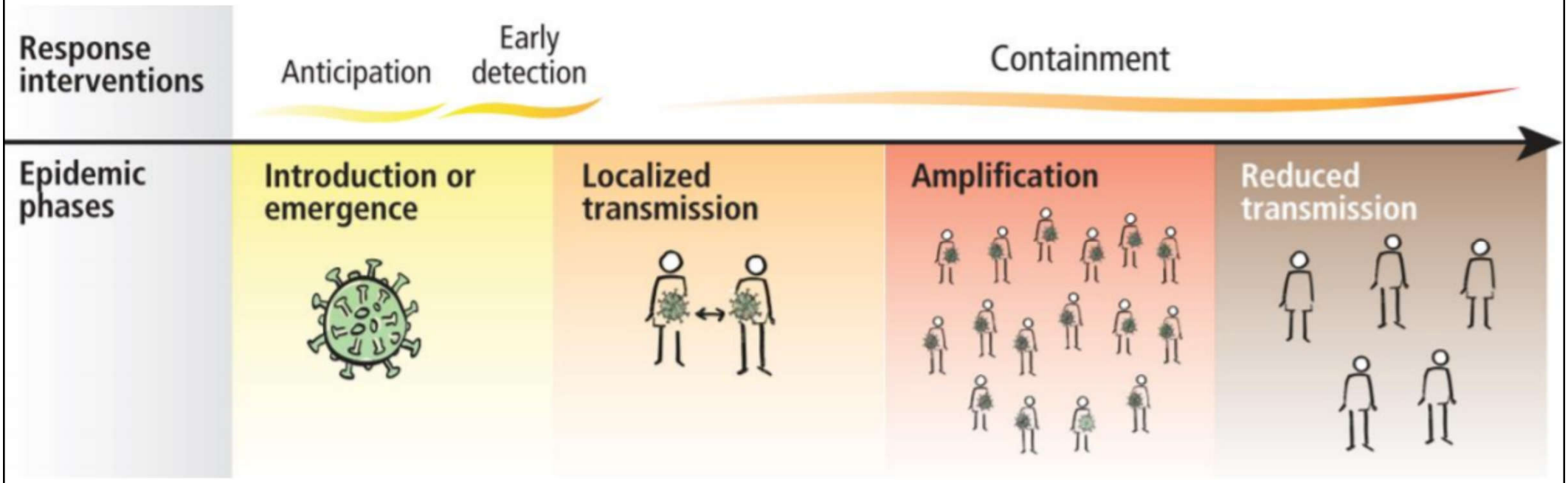
(Source: https://www.phe.gov/emergency/events/COVID19/Documents/COVID-19%20Healthcare%20Planning%20Checklist.pdf)

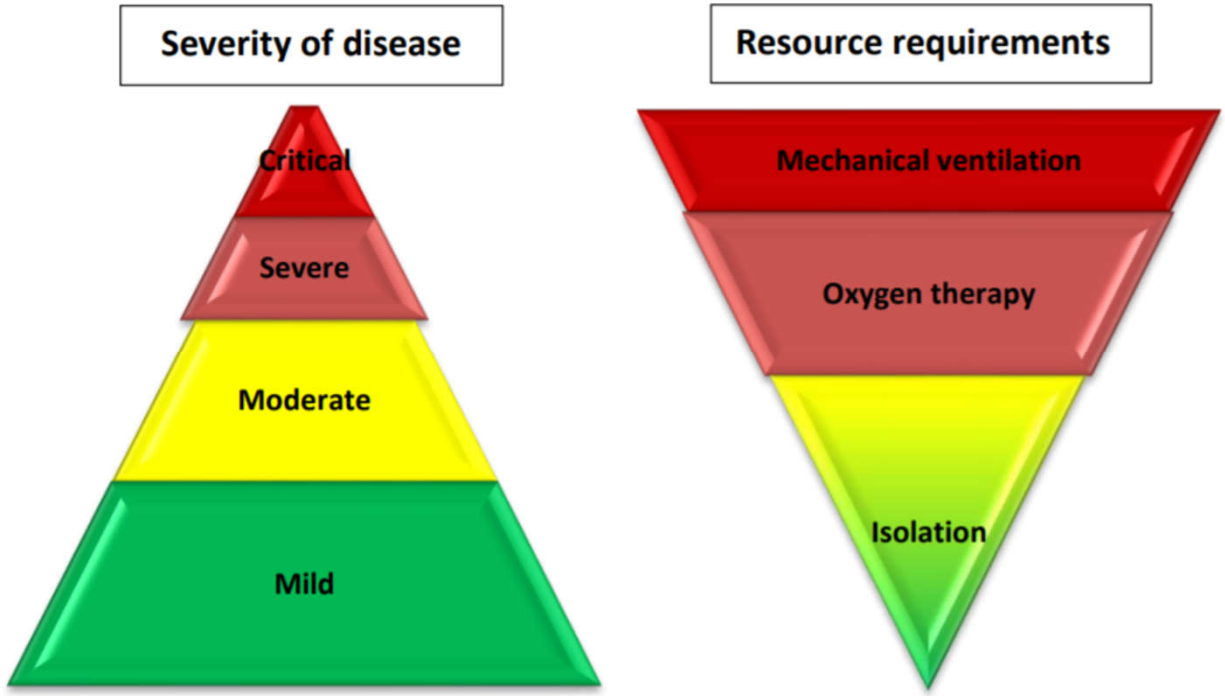
Strategy for planning and preparedness

- **WHO Operational considerations for case management of COVID-19 in health facility and community: Interim guidance, 19 March 2020**
  - 1. Key public health interventions regardless of transmission scenario
  - 2. Key action steps to be taken by transmission scenario to enable timely surge of clinical operations
- Public health objectives:
  - Prevent outbreaks, delay spread, slow & stop transmission
  - Provide optimized care for all patients, especially the seriously ill
  - Minimize the impact of the epidemic on health systems, social services & economic activity

(Source: WHO Operational considerations for case management of COVID-19 in health facility and community: Interim guidance, 19 March 2020 https://apps.who.int/iris/bitstream/handle/10665/331492/WHO-2019-nCoV-HCF_operations-2020.1-eng.pdf)

Case management of COVID-19 in health facility & community





(Source: WHO Operational considerations for case management of COVID-19 in health facility and community: Interim guidance, 19 March 2020 https://apps.who.int/iris/bitstream/handle/10665/331492/WHO-2019-nCoV-HCF_operations-2020.1-eng.pdf)

Screening for COVID-19 to the health system

SCREEN FOR COVID-19 AT FIRST POINT OF ACCESS TO THE HEALTH SYSTEM

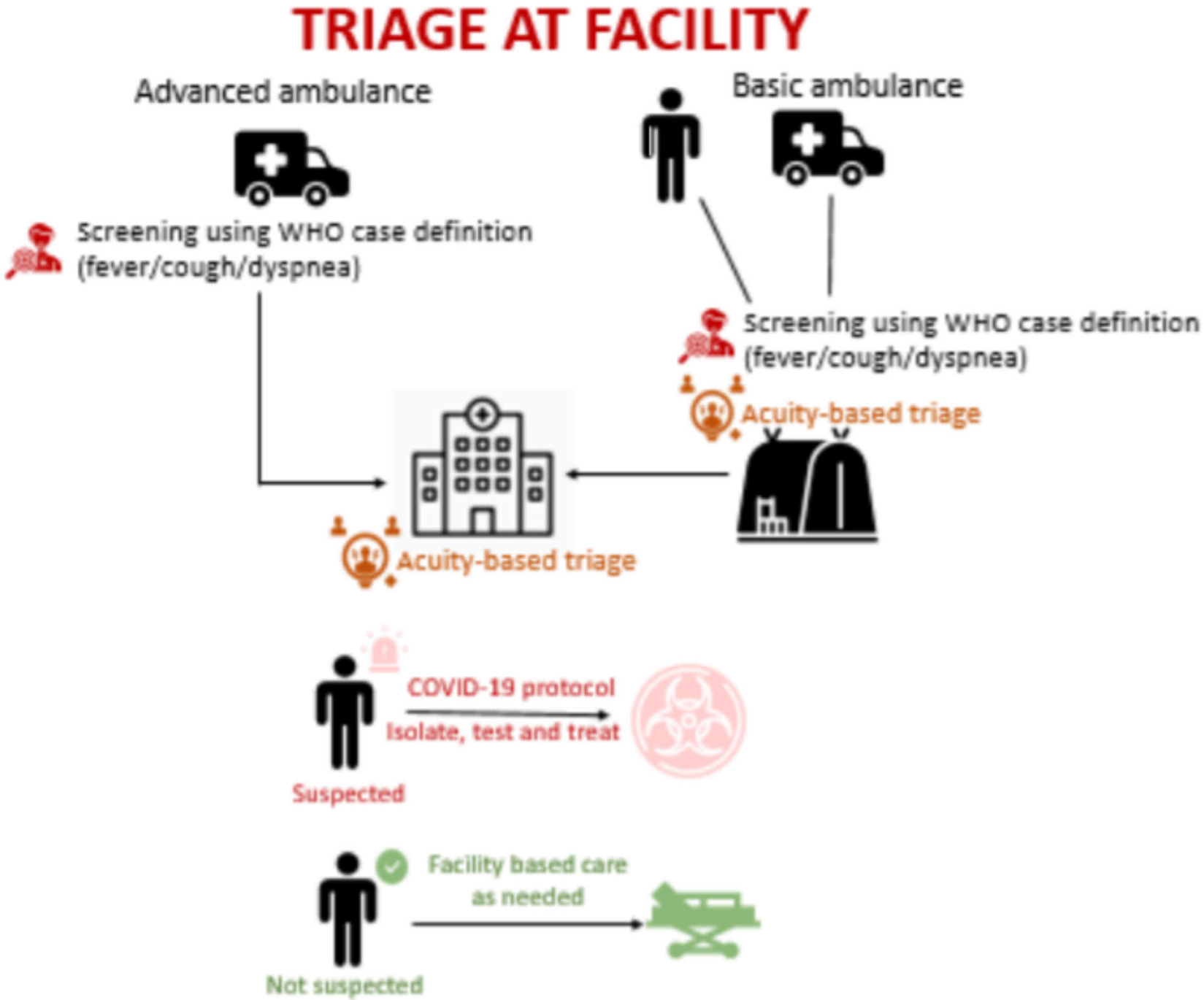
*All patients should be screened for COVID-19 using WHO Case Definitions at the first point they access the health system.

APPLY WHO CASE DEFINITION
(fever, cough, dyspnea)

Patients suspected to have COVID-19	Patients NOT suspected to have COVID-19
Refer to appropriate facility or testing site as per local protocol	Management as per local protocol (routine management or referral as per reorganization of service delivery)

(Source: WHO Operational considerations for case management of COVID-19 in health facility and community: Interim guidance, 19 March 2020 https://apps.who.int/iris/bitstream/handle/10665/331492/WHO-2019-nCoV-HCF_operations-2020.1-eng.pdf)

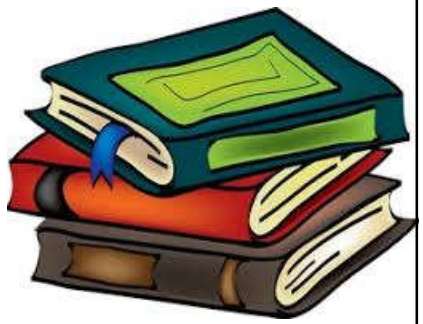
Triage (分流) for early recognition & source control



(Source: WHO Operational considerations for case management of COVID-19 in health facility and community: Interim guidance, 19 March 2020 https://apps.who.int/iris/bitstream/handle/10665/331492/WHO-2019-nCoV-HCF_operations-2020.1-eng.pdf)

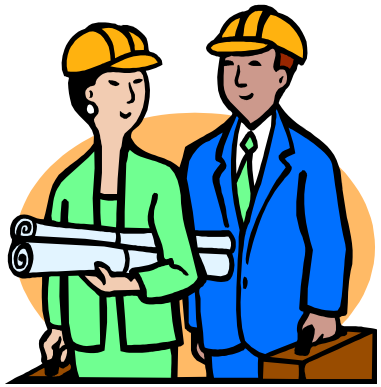
Strategy for planning and preparedness

- Health Facility Guidelines (selected ones):
  - Australasian Health Facility Guidelines (AusHFG) https://www.healthfacilityguidelines.com.au/
  - Facility Guidelines Institute (FGI), USA https://fgiguidelines.org/
  - International Health Facility Guidelines http://www.healthfacilityguidelines.com/
  - UK Dept. of Health (DH) Health Building Notes https://www.gov.uk/government/collections/health-building-notes-core-elements



Strategy for planning and preparedness

- Typical planning issues (new facilities):
  - Site selection & development
  - Masterplan development
  - Local design regulations
  - Land area measurement methodology & definitions
  - Floor area measurement methodology, definitions & diagrams
  - Parking & vehicular access



Strategy for planning and preparedness

- Major factors:
  - Hardware: Health care facilities, laboratories, supporting facilities
  - Software: Workforce (staff) - human resources & operational leaders
  - Supplies: Materials, equipment & devices
- Testing laboratories:
  - Capacity for COVID-19 large-scale testing
  - Off-site screening & testing stations (if needed)

Strategy for planning and preparedness

- Risk assessment & response
  - A multidisciplinary team (e.g., facility engineer, infection preventionist, risk manager, sterile processing manager or other designated personnel) should conduct a risk assessment

  - Include healthcare technology management (HTM) & sterilization professionals
  - Engage rapid response & case investigation teams
    - For quick reaction & contact tracing

  - Contingency planning & appropriate response

Useful COVID-19 resources for health care facilities

- ASHRAE COVID-19 (Coronavirus) Preparedness Resources http://ashrae.org/COVID19
- ASHRAE TC 9.6 Healthcare Facilities http://tc0906.ashraetcs.org/
- American College of Healthcare Executives (ACHE) COVID-19 Resource Center https://ache.org/COVID
- American Hospital Association (AHA) https://www.aha.org/2020-01-22-updates-and-resources-novel-coronavirus-2019-cov
- American Society of Health Care Engineering (ASHE) http://www.ashe.org/COVID19resources
- Association for the Health Care Environment (AHE) https://www.ahe.org/covid-19-resources-evs-professionals-2020
- CDC Resources for Clinics and Healthcare Facilities http://www.cdc.gov/coronavirus/2019-ncov/healthcare-facilities/
- WHO Technical Guidance - Coronavirus disease (COVID-19) https://www.who.int/emergencies/diseases/novel-coronavirus-2019/technical-guidance

Strategy for planning and preparedness

- Practical issues to consider:
  - Understand the current facilities
    - Existing facility assessments (potential & limitations)
    - Prepare for emergency scenarios; hospitals must be able to react to a variety of circumstances
  - Additions, renovations & upgrades
    - Expand & renovate existing occupied hospitals (plan for noise problems & disruptions)
  - Converting buildings/sites on an ad hoc basis
    - For health care & quarantine facilities

Strategy for planning and preparedness

- **Pandemic Preparedness:**
  - How hospitals can adapt buildings to address worst-case scenarios https://www.bdcnetwork.com/blog/pandemic-preparedness-how-hospitals-can-adapt-buildings-address-worst-case-scenarios
    - 1. Including separate emergency entrances for contagious patients
    - 2. Transforming hospital lobbies - as well as other external spaces - for patient pre-screening
    - 3. Controlled separation between patients, visitors, and staff, based upon specific illnesses & their related level of contagion
    - 4. Providing the ability to convert existing hospital spaces - during a pandemic - into patient treatment spaces

Strategy for planning and preparedness

- Technology potential for COVID-19:
  - Telehealth or Telemedicine 遠程醫療
  - Artificial Intelligence (AI) 人工智能 (e.g. AI chatbot, fever detection cameras)
  - Robotics (e.g. for delivery, cleaning & disinfection)
  - Digital contact tracing (e.g. location-tracking apps)




Strategy for planning and preparedness

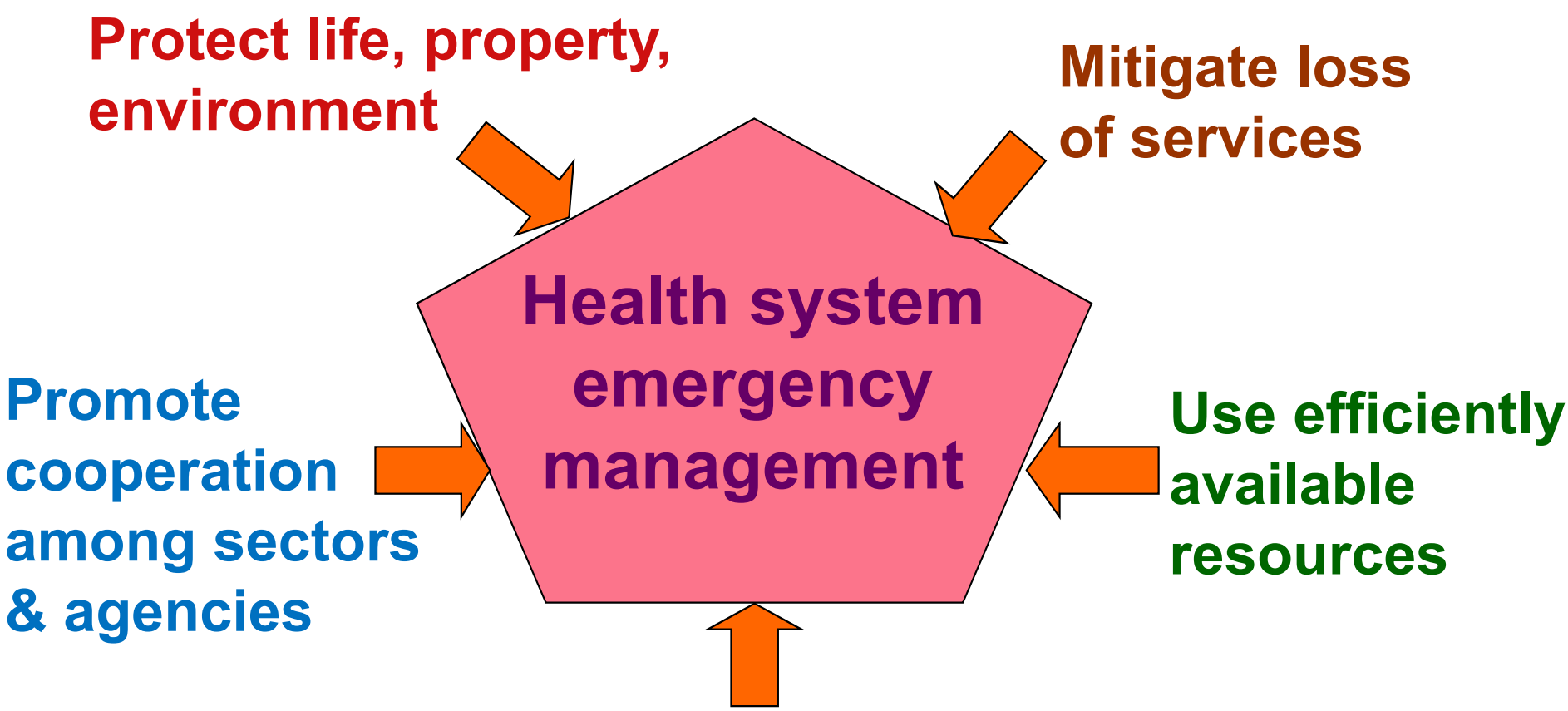
- Telehealth in the time of COVID-19 https://www.mobihealthnews.com/news/europe/telehealth-time-covid-19
  - For patients: self-isolated/home-isolated patients (self & distance monitoring), patients with mild cases (distance monitoring & treatment), patients after discharge (follow-ups)

  - For health workers: clinicians with mild symptoms can still work remotely with patients, retired clinicians, second opinion for severe cases, cross-border experience exchange, teleradiology, online trainings for health workers

Emergency management

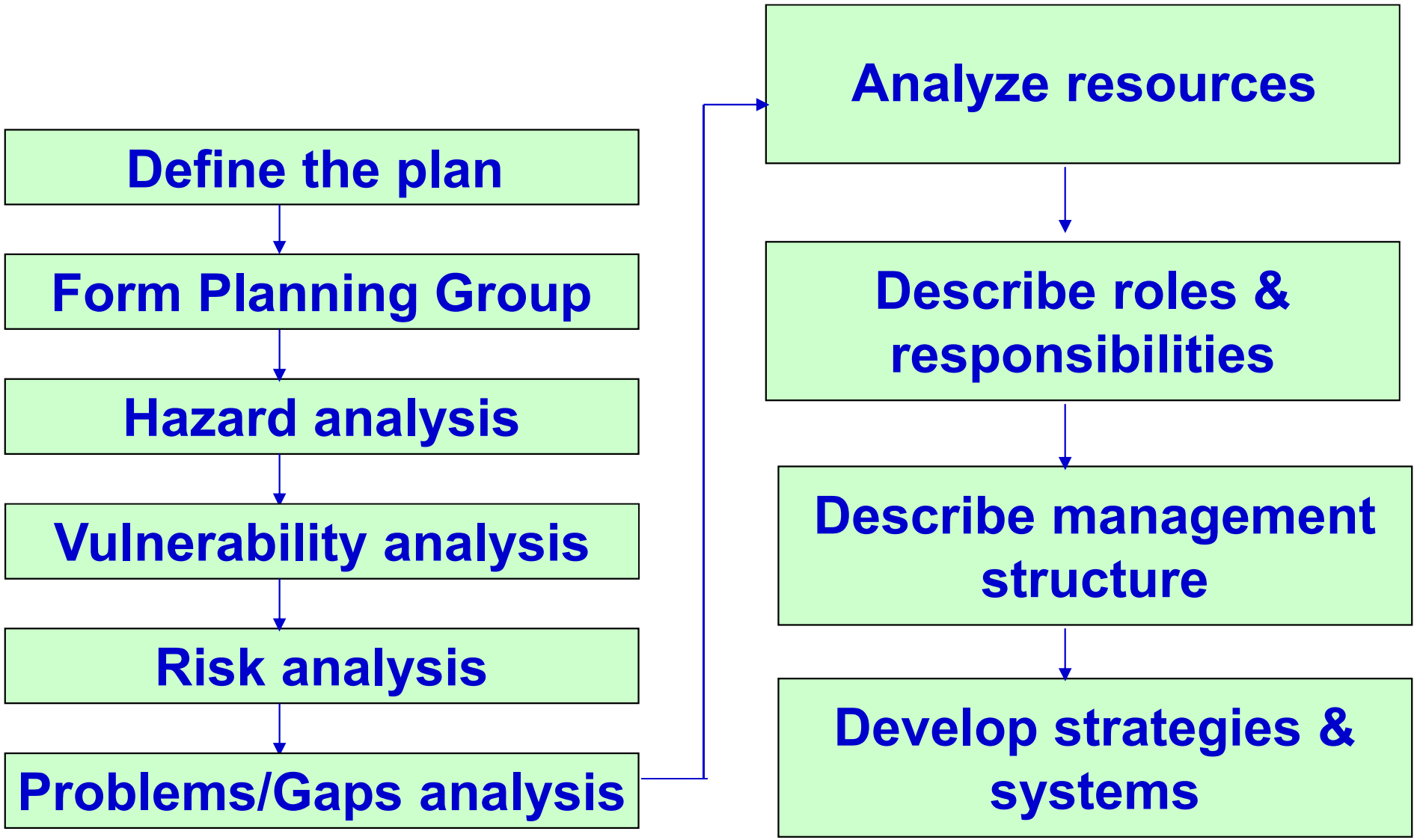
- **Pandemic risk management:**
  - Risk assessment and impacts on health system capacity & social institutions (e.g. elderly care)
  - Crisis management: require a rapid response
    - Shift from a containment to a mitigation approach
    - Community engagement & stringent social distancing
  - Protect the vulnerable populations, health care workers & first responders
  - Business continuity & provision of other essential healthcare services

Key concepts of health system emergency management



(References: Health emergency and disaster risk management https://www.who.int/hac/techguidance/preparedness/; Guidelines for Developing Hospital Emergency Management Plan http://asdma.gov.in/pdf/publication/undp/guidelines_hospital_emergency.pdf)

Emergency planning process



(References: Health emergency and disaster risk management https://www.who.int/hac/techguidance/preparedness/; Guidelines for Developing Hospital Emergency Management Plan http://asdma.gov.in/pdf/publication/undp/guidelines_hospital_emergency.pdf)

Emergency management

- **Principles and coordination:**
  - Four principles of emergency management: mitigation, preparedness, response & recovery
  - Coordination on health, education, travel & tourism, social protection, business, public works
  - Initial capacity assessment & risk analysis, including mapping of vulnerable populations
    - Such as elderly, disabled, pregnant women & children
  - Surge plans to manage increased demand for testing, screening, quarantine & treatment

Emergency management

- **Key components of hospital emergency response:**
  - 1. Command & control
  - 2. Communication
  - 3. Safety & security
  - 4. Triage
  - 5. Surge capacity
  - 6. Continuity of essential services
  - 7. Human resources
  - 8. Logistics & supply management
  - 9. Post-disaster recovery

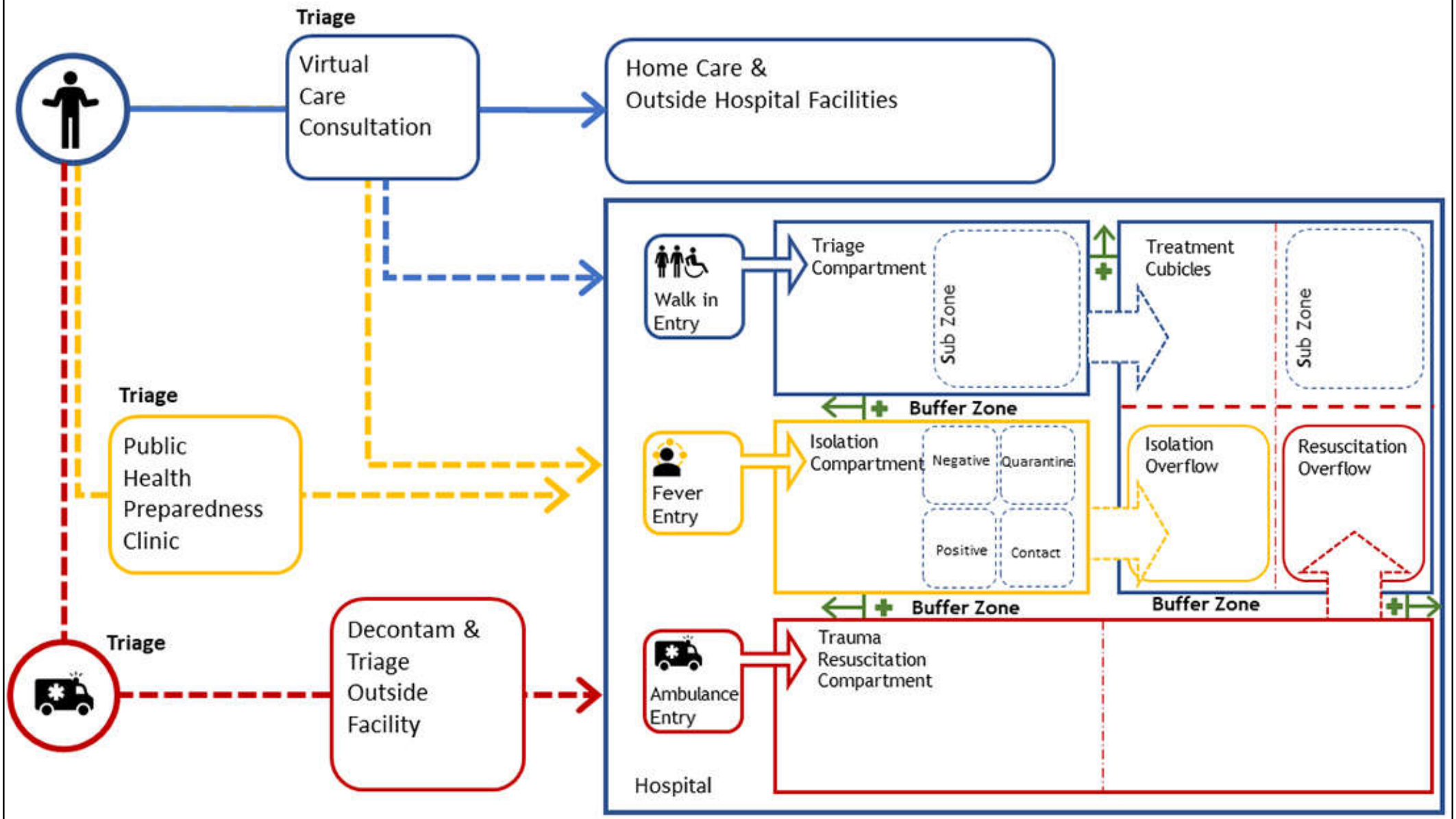
(Reference: Hospital emergency response checklist https://www.who.int/publications-detail/hospital-emergency-response-checklist)

Emergency management

- **Manage COVID-19 suspected cases:**
  - Hospitals have AII Rooms, e.g. 1-2 per patient floor or suite
    - These rooms would normally be used for suspected COVID patients, along with other infectious conditions e.g. Tuberculosis
    - As numbers increase, too few AII rooms may be available to house suspected COVID patients
  - The general course of growth from suspected cases to a high number of confirmed cases is commonly shorter than the time frame for treatment & release of "first in" patients, so it is important to recognize that committing AII rooms to patients limits future flexibility
  - Ensure hospital resilience to maintain critical functions

(Reference: COVID 19 Guidance by Michael Sheerin https://www.bdcnetwork.com/tlccovid-19ventilationguidance)

Segmenting hospital patient flows in the case of surge scenarios (an example from Singapore)



(Source: It's not if, but when: Designing healthcare spaces that support pandemic response https://www.bdcnetwork.com/blog/it%E2%80%99s-not-if-when-designing-healthcare-spaces-support-pandemic-response)

Emergency management

- **Pandemic response:**
  - Facilities could consider designating entire units to care for known or suspected COVID patients
    - Staffed with dedicated healthcare personnel to limit exposure risk
  - Clinicians have advocated against cohorting suspected & confirmed patients in the same unit/ward, to avoid the potential for conversion
  - Temporary patient segregation plan is required for safe segregation of suspected & confirmed patients
  - Set up testing & screening sites exclusively for identifying COVID-19 positive patients in a safe environment

Emergency management

- Clinical modes & operation in hospitals:
  - 1. Normal mode (use existing AII rooms)
  - 2. Small scale surge capacity mode (e.g. create additional dedicated AII or temporary patient observation/segregation rooms with HEPA & negative pressure)
  - 3. Large scale surge capacity mode – may be asked to establish dedicated ward(s)
  - [Remark: temporary patient observation/segregation areas are not true AII rooms]

(Reference: COVID 19 Guidance by Michael Sheerin https://www.bdcnetwork.com/tlccovid-19ventilationguidance)

Emergency management

- Emergency Department (ED)
  - Accident and Emergency (A&E) 急症室 - frontline first responder & transport of patients
  - Restrict access to ED & increase protection measures
  - Use of negative pressure ambulance (負壓救護車) or chambers
  - Evaluation & management of COVID patients
    - Persons Under Investigation (PUI) capable of self care are triaged outside the ED, either through screening stations set up in tent or temporary space, and advised to continue home care until results are available

(Reference: American College of Emergency Physicians (ACEP) https://www.acep.org/corona/COVID-19/)

Emergency management

- Outpatient & residential facilities 門診和住院設施
  - Precautions for COVID cases
    - Handling of suspected/confirmed case; patient placement/transfer
  - Staff sickness monitoring: checking staff (before every shift) & visitors for flu-like conditions, temperature & travel history
  - Managing visitors: restricting visitors to a resident room or halting visits altogether
  - Environmental cleaning, disinfection & decontamination
  - Special considerations for vulnerable populations (e.g. in nursing homes 療養院)

(Reference: Reducing the risk of transmission of COVID-19 in the hospital setting (Updated 17 April 2020) https://www.gov.uk/government/publications/wuhan-novel-coronavirus-infection-prevention-and-control/reducing-the-risk-of-transmission-of-covid-19-in-the-hospital-setting)

Emergency management

- How to increase capacity of facilities in emergencies
  - Hospital resilience & response to unexpected challenges
  - Design for adaptability, free up capacity at the main hospitals for extraordinary situations, in patient care spaces or temporary spaces when surges occur
  - Flexibility of transforming regular rooms into isolation units & expanding critical intensive care units (ICUs)
  - Modify hospitals, smaller facilities & spare spaces to meet the surge demand and to increase areas for medical screening, triage & other patient care
  - Relocate service to another location in a hospital network

Designing healthcare for surge capacity

1. Repurposing existing facilities (e.g. sports stadiums, convention centres, hotels, or student housing)
2. Rethinking the hospital (assess non-clinical spaces & spaces capable of performing multiple functions easily)
3. Putting support spaces to work (facilities that can be converted quickly in a matter of hours)
4. Reactivating former patient care spaces (reuse outdated patient care towers for administrative or other non-patient facing functions)
5. Modular outpatient thinking (for the compartmentalization required for infectious populations)
6. Investing in caregivers (require dedicated healthcare professionals & workforce)

(Source: https://www.gensler.com/research-insight/blog/designing-healthcare-for-surge-capacity)

Emergency management

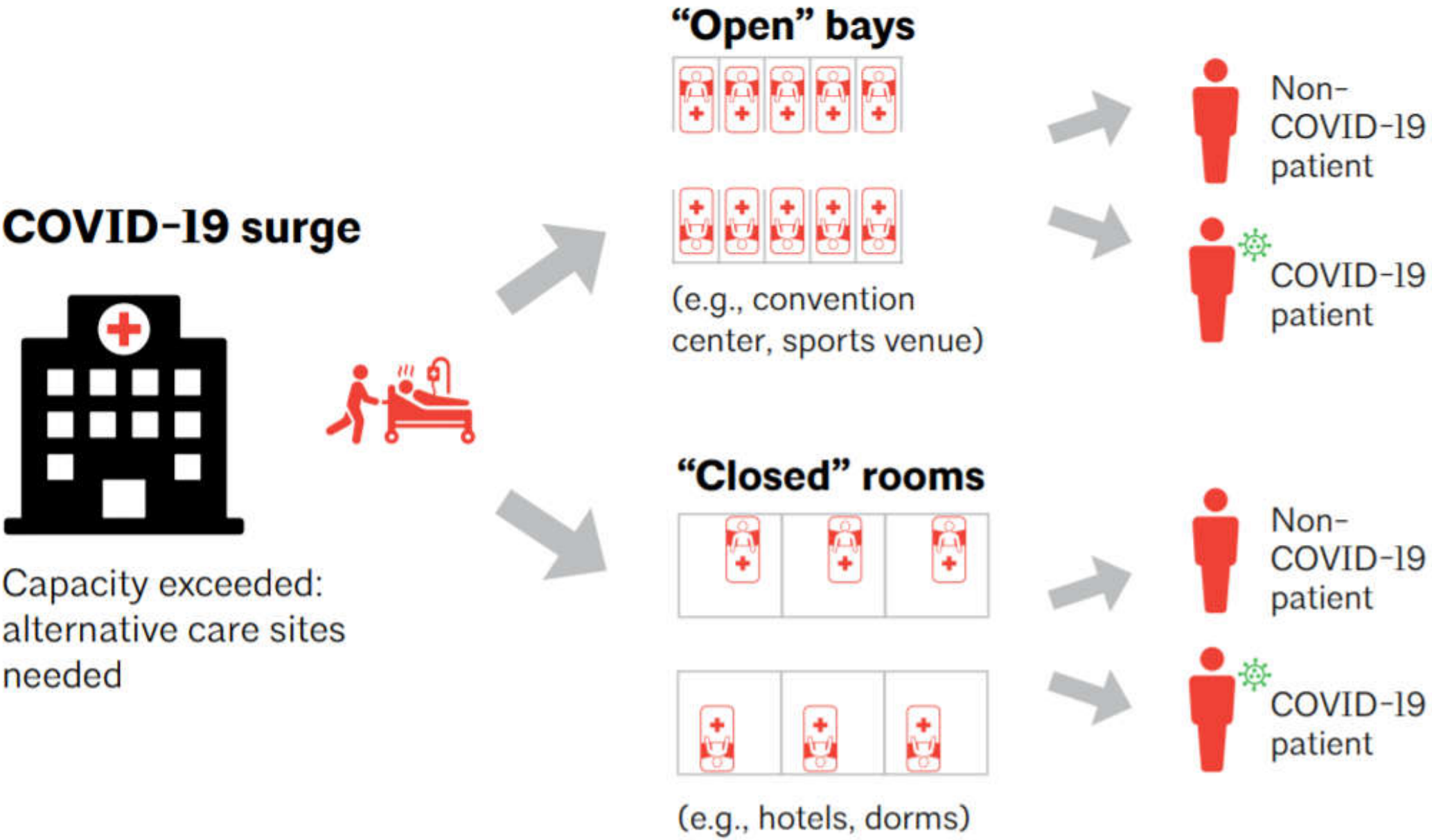
- **Alternative health care facilities**
  - In response to bed shortage & facility saturation
    - More flexibility to provide hospital services
    - Adapt other buildings or sites into health care facilities
  - Major issues to consider:
    - Fast assembled & efficient design (very tight timetable)
    - Pre-existing structures that can quickly be adapted (a structure with a robust mechanical system, significant plumbing capacity & an existing fire rating)
    - Proximity to adjacent medical services (to readily share resources, supplies & personnel)
    - Develop a systematic framework for conversion

(Reference: Alternative Healthcare Facilities: Architects Mobilize their Creativity in Fight against COVID-19 https://www.archdaily.com/937840/alternative-healthcare-facilities-architects-mobilize-their-creativity-in-fight-against-covid-19)

Emergency management

- Adaptive reuse of buildings in a pandemic scenario
  - Also known as ***Alternate Care Sites (ACS)***
  - Should consider both safety & functionality, not solely bed counts; usually provide the minimum requirements for patient & staff safety only
  - Create a strategy for the short term & long term
  - Adapt existing buildings for health care operations
    - 1. "Open" structures e.g. convention centres, stadium, enclosed sports venues
    - 2. "Room-based" structures e.g. hotels & dormitories, are also a consideration, particularly newer facilities that have ventilation & bathroom facilities for distinct separation of patients

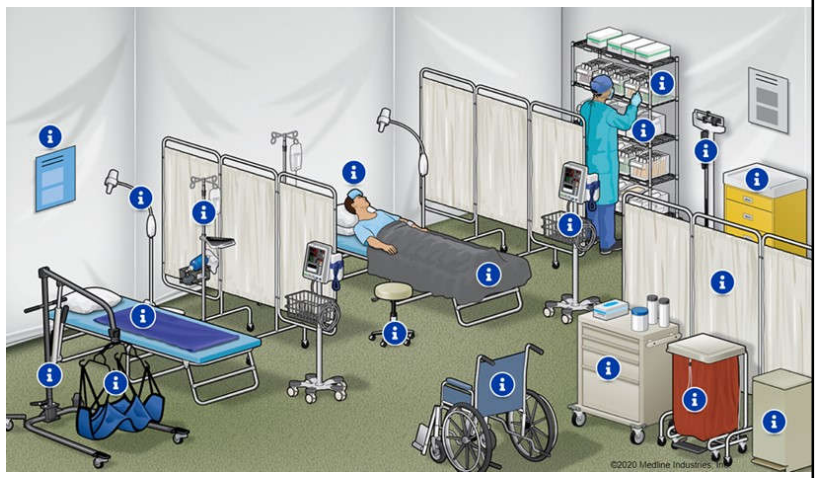
Alternate Care Sites (ACS) to cope with the surge



(Source: AIA COVID-19 Task Force 1: Health Impact Briefing #1, April 6, 2020. COVID-19 alternative care sites: Addressing capacity, safety, & risk challenges for our nation's hospitals during a public health pandemic response http://content.aia.org/sites/default/files/2020-04/KC20_AAH_C-19_Alt-Care-Sites-Whitepaper_sm_v03_FINAL.pdf)

Emergency management

- How to safely & effectively provide healthcare operations within a non-healthcare setting
  - Can use a hotel for patients needing less intensive care while using inpatient beds for COVID-19 patients
- Key factors:
  - Site selection, roadway access & security
  - Building size considerations
  - Building security
  - Clinical considerations
  - Physical configuration



(Reference: COVID-19 Alternate Care Site Resources https://asprtracie.hhs.gov/technical-resources/111/covid-19-alternate-care-site-resources/99)

Emergency management

- Alternate Care Sites (ACS) implementation process
  - 1. Identify potential sites (e.g. hotel, arena, closed hospital)
  - 2. Conduct site assessments
  - 3. Secure funding
  - 4. Secure property
  - 5. Convert site for healthcare use
  - 6. Secure wraparound services (food, transport, ambulance, waste, laundry & fencing)
  - 7. Staff, equipment & supplies
  - 8. Operate site (roles & responsibilities, flow, security, etc)
  - 9. Restore site

(Source: US Army Corps of Engineers (USACE) - Alternate Care Sites (ACS) https://www.usace.army.mil/Coronavirus/Alternate-Care-Sites/)

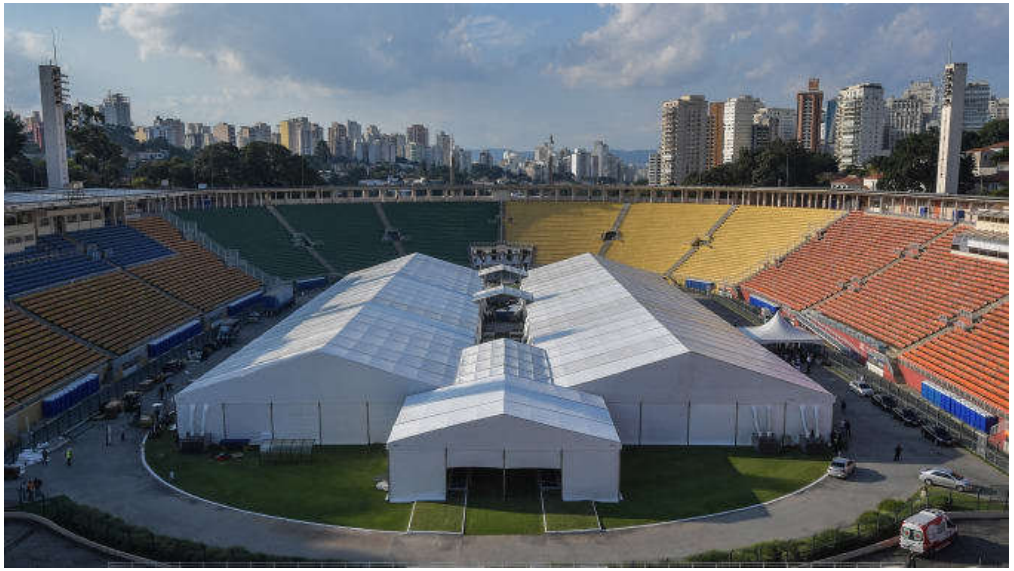
Emergency management

- **Emergency field hospitals for COVID-19**
  - Temporary field hospitals were set up for:
    - (a) COVID-19 patients with mild or no symptoms
    - (b) Patients who need treatment & intensive care
  - Have different characteristics & functions, depending on purpose, budget & location
  - Prefabricated modules can be used to speed up, e.g.
    - https://www.alibaba.com/showroom/modular-hospital.html
    - https://www.medifa.com/notfall-intensivstation/?lang=en
    - https://hga.com/staat-mod

Emergency management

- Examples of temporary hospitals:
  - Makeshift & field hospitals
    - Huoshenshan Hospital (火神山醫院), Leishenshan Hospital (雷神山醫院) in Wuhan
    - Fangcang shelter hospitals (方艙醫院) in China
    - The new NHS Nightingale Hospitals in UK
    - Field hospitals in Brazil, Italy, Russia, Spain & USA
  - Hospital ships or floating hospitals
    - US Navy hospital ships USNS Comfort & Mercy

Examples of field hospitals set up to treat COVID-19 patients



Brazil: Pacaembu stadium in Sao Paulo

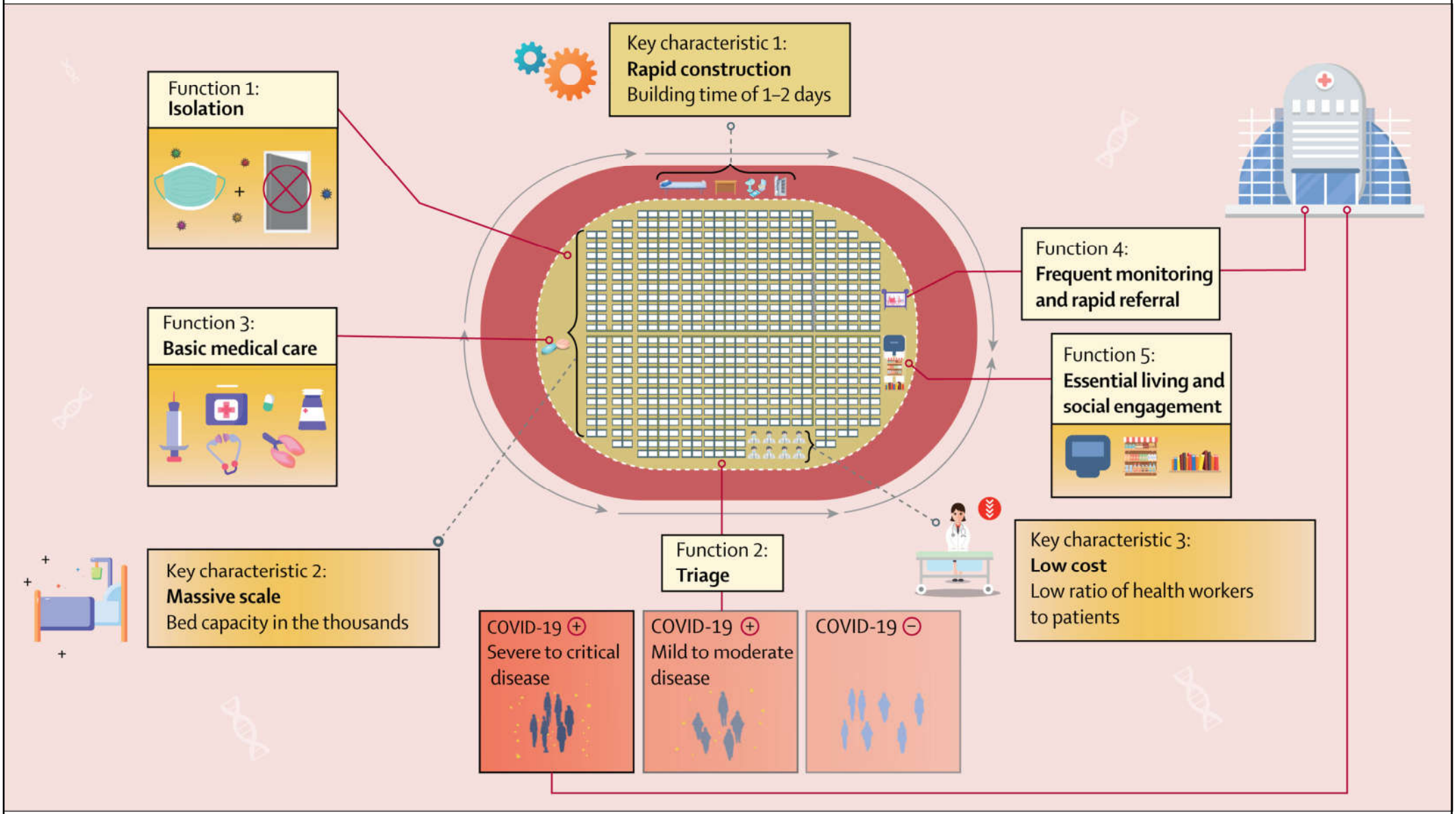
China: A sports stadium in Wuhan

USA: Jacob K. Javits Center in New York City

Spain: Fira Barcelona Montjuic centre in Barcelona

(Source: https://www.cnbc.com/2020/04/03/photos-of-field-hospitals-set-up-around-the-world-to-treat-coronavirus-patients.html)

Key characteristics and essential functions of Fangcang shelter hospitals (方艙醫院)



(Source: Chen, S. et al., 2020. Fangcang shelter hospitals: a novel concept for responding to public health emergencies, *Health Policy*, 395 (10232): 1305-1314. https://doi.org/10.1016/S0140-6736(20)30744-3)

Huoshenshan Hospital in Wuhan 武漢火神山醫院

图 1：火神山医院每个护理单元有 50 床，每 4 个单元为 1 个医疗区

数据来源：网易新闻，中信建筑设计院

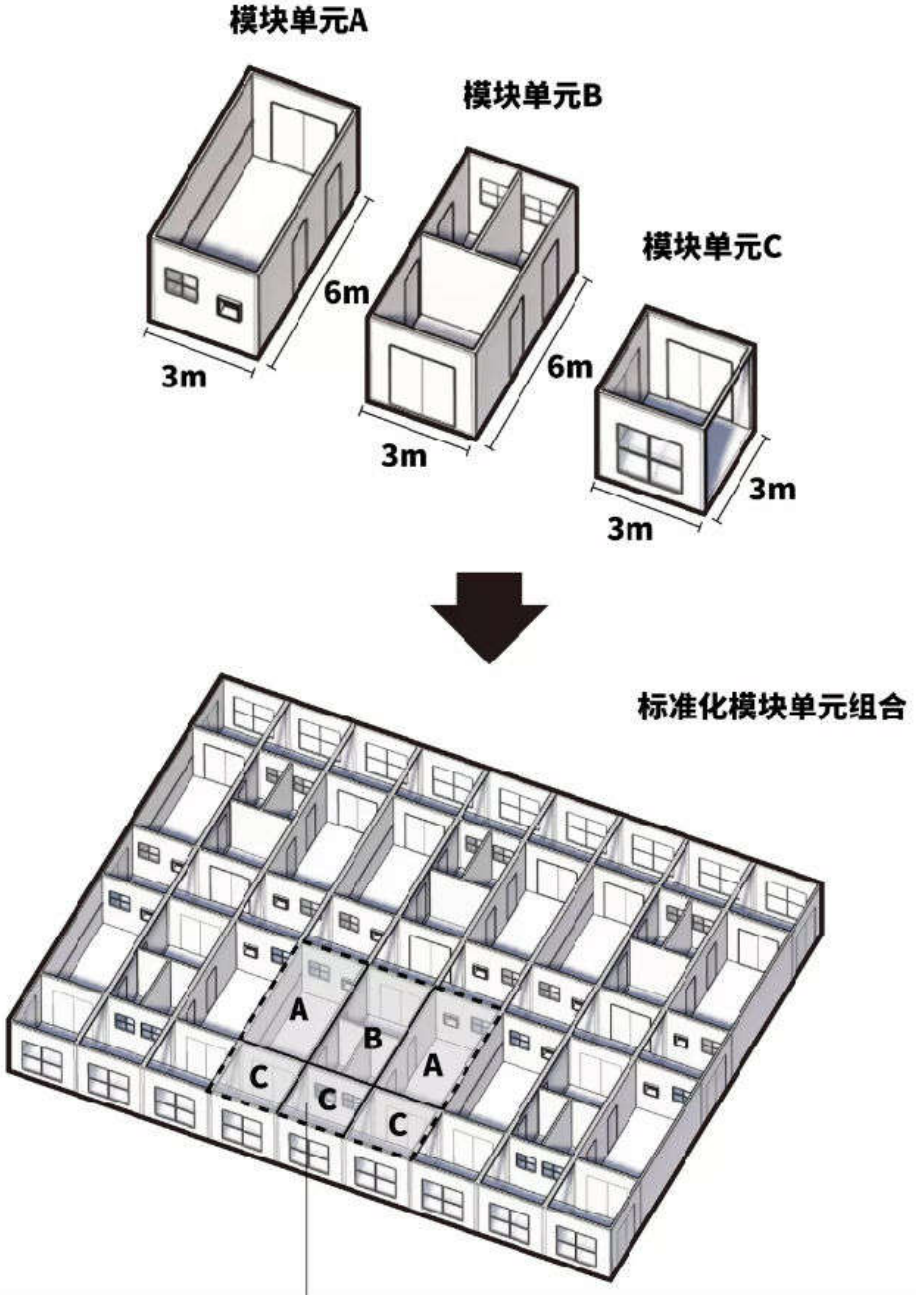


图 2：火神山医院平面图呈现 L 型

数据来源：网易新闻

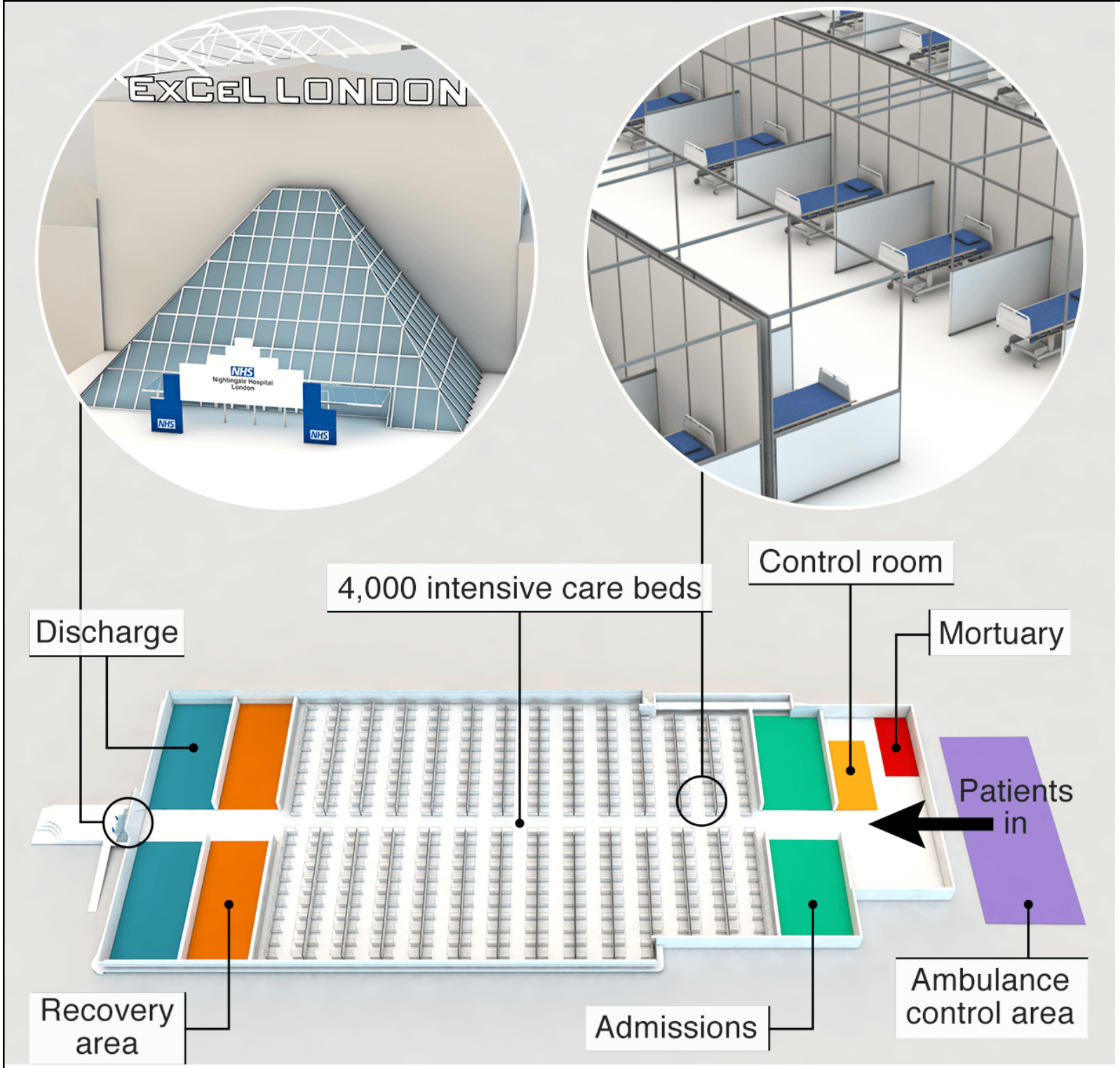
图 3：火神山医院病房效果图

数据来源：网易新闻

(Source: 从火神山、雷神山医院看装配式钢结构的应用_证券公司研报 http://www.precast.com.cn/index.php/subject_detail-id-14514.html ; 火神山房屋结构是啥样的？ http://www.precast.com.cn/index.php/subject_detail-id-14565.html)

Building the New NHS Nightingale Hospital in East London's ExCeL exhibition centre in just nine days

(Source: How NHS Nightingale was built in just nine days https://www.bbc.com/news/health-52125059)



The temporary NHS Nightingale hospital has space for 4,000 intensive care beds

(Source: How NHS Nightingale was built in just nine days https://www.bbc.com/news/health-52125059)

Emergency management

- Converting hotels into hospitals or quarantine sites
  - In pandemic, hospitals are overflowing; hotels are empty
  - Which hotels & for what medical needs? Four scenarios:
    - 1. To quarantine suspected or asymptomatic patients
    - 2. Non-COVID-19 positive patients in recovery who don't require life-support equipment (relocate them to free up hospital beds)
    - 3. Non-COVID-19 positive patients in recovery that require specialized & powered equipment
    - 4. COVID-19 positive patients in treatment
  - Key considerations: cleanable surfaces, mechanical & electrical systems, nurse-call devices & handwash sinks

(References: https://www.bdcnetwork.com/covid-19-innovation-setting-parameters-hotel-hospital-conversions; https://www.bdcnetwork.com/cities-scramble-hospital-beds-treat-covid-19-patients-leo-daly-offers-hotel-hospital-solution)

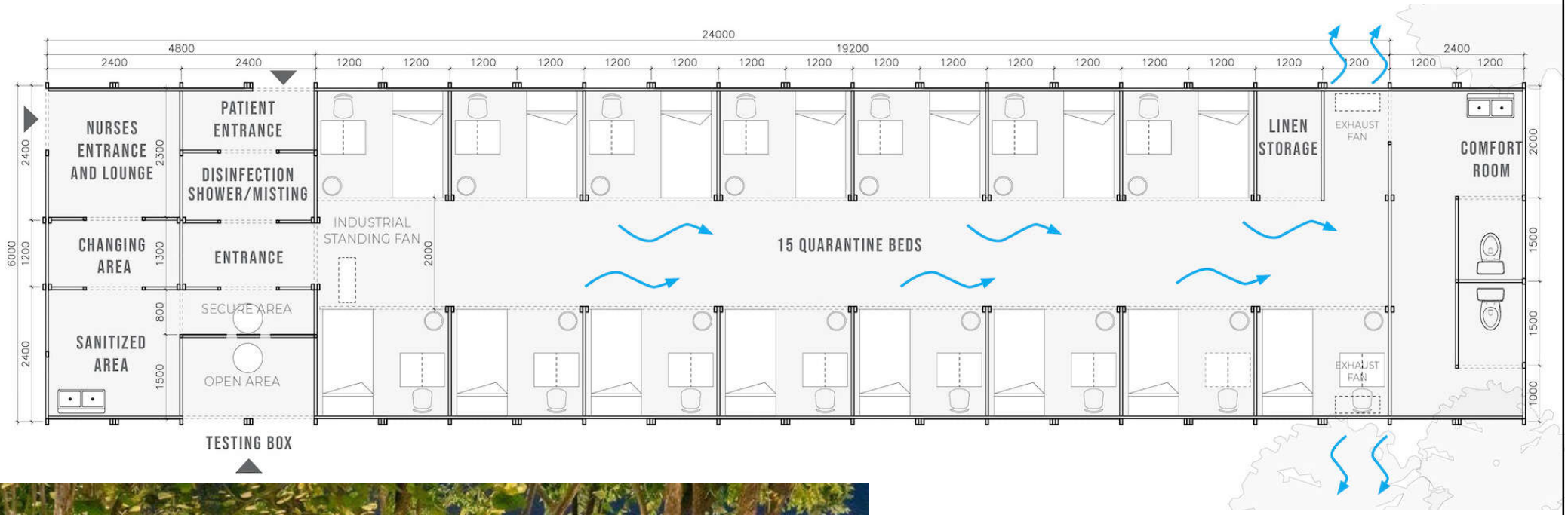
Emergency management

- **Quarantine facilities 檢疫設施**
  - Healthcare & quarantine needs increase from the pandemic
  - Also housing clinical staff to treating low-acuity patients
  - Emergency quarantine facility - unoccupied/acquired buildings, temporary shelters/pavilions, hotels/dorms
    - Key factors: Speed, readily available, location & scalability
  - Examples:
    - Hong Kong: Recreation centre, holiday village, training camp, newly built public housing, modular units, hotel
    - Philippines: Temporary structures built on site https://www.wtadesignstudio.com/eqf/

Quarantine camp set up at Lei Yue Mun Park and Holiday Village

(Source: https://www.scmp.com/news/hong-kong/health-environment/article/3052522/coronavirus-new-hong-kong-quarantine-camps-cost)

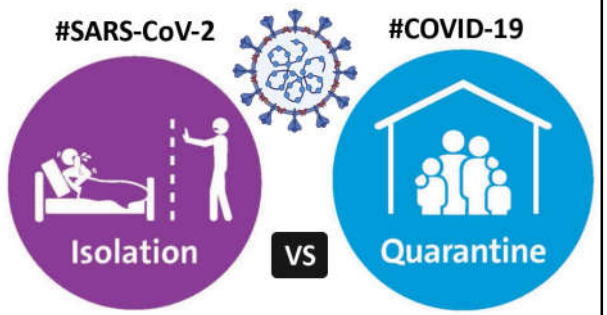
Temporary/Emergency quarantine facilities (Manila, Philippines)



(Source: https://www.architecturalrecord.com/articles/14553-manila-based-architecture-firm-designs-temporary-quarantine-facilities; https://www.wtadesignstudio.com/eqf/)

Emergency management

- Quarantine vs Isolation:　檢疫 vs 隔離
  - **Quarantine** is the restriction of activities or separation of persons (in a non-health care facility) who are not ill, but who might have been exposed to infection, with the objective of monitoring symptoms & early detection of cases, for preventing transmission of diseases
    - Usually quarantined in their homes or community-based facilities
  - **Isolation**, different from quarantine, is the separation of ill or infected persons from others, so as to prevent the spread of infection or contamination
    - Using isolation rooms or facilities

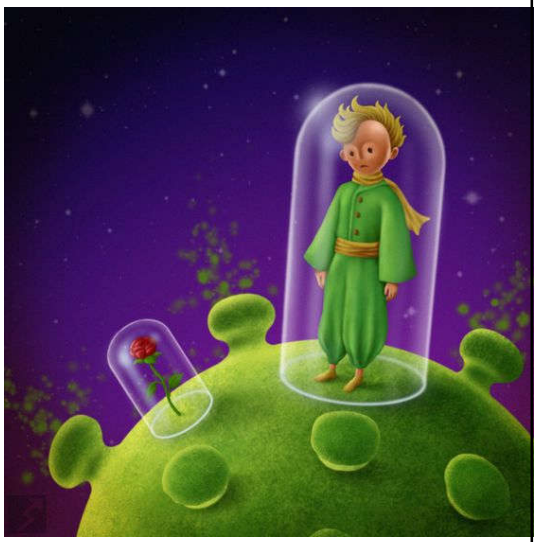


Mobile quarantine facility: The crew of Apollo 11 in quarantine after returning to Earth, visited by Richard Nixon.

(Source: https://en.wikipedia.org/wiki/Mobile_quarantine_facility)

Emergency management

- Guidelines for quarantine facilities:
  - Evaluation of potential sites
  - Risk assessment
  - Securing entry & exit points
  - Human resource arrangement
  - Coordination, monitoring & supervision
  - Logistic management, cleaning & supplies
  - Social support and recreation



(Source: Guidelines for Quarantine Facilities COVID-19 - NCDC, India https://ncdc.gov.in/WriteReadData/l892s/90542653311584546120.pdf; Guidelines: Establishing Quarantine Facility https://www.nih.org.pk/wp-content/uploads/2020/03/20200325-Guidelines-for-Quarentine-Facility-Establishment-0301-1.pdf)

Conclusion

- COVID-19 crisis will not end soon ☹ ☹ ☹
  - Successful pandemic response requires close coordination between the health system & the greater community
- Engineering support is crucial for tackling the public health emergency
  - To leverage problem-solving skills to optimize safety & mitigate risk in health care facilities
  - Engineers could help in master planning, risk assessment, troubleshooting & solving technical problems
- We should learn from the mistakes made before (e.g. SARS 2003)

THANK YOU 謝謝 !!

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