# ENGINEERING APPROACHES TO AIRBORNE INFECTION CONTROL

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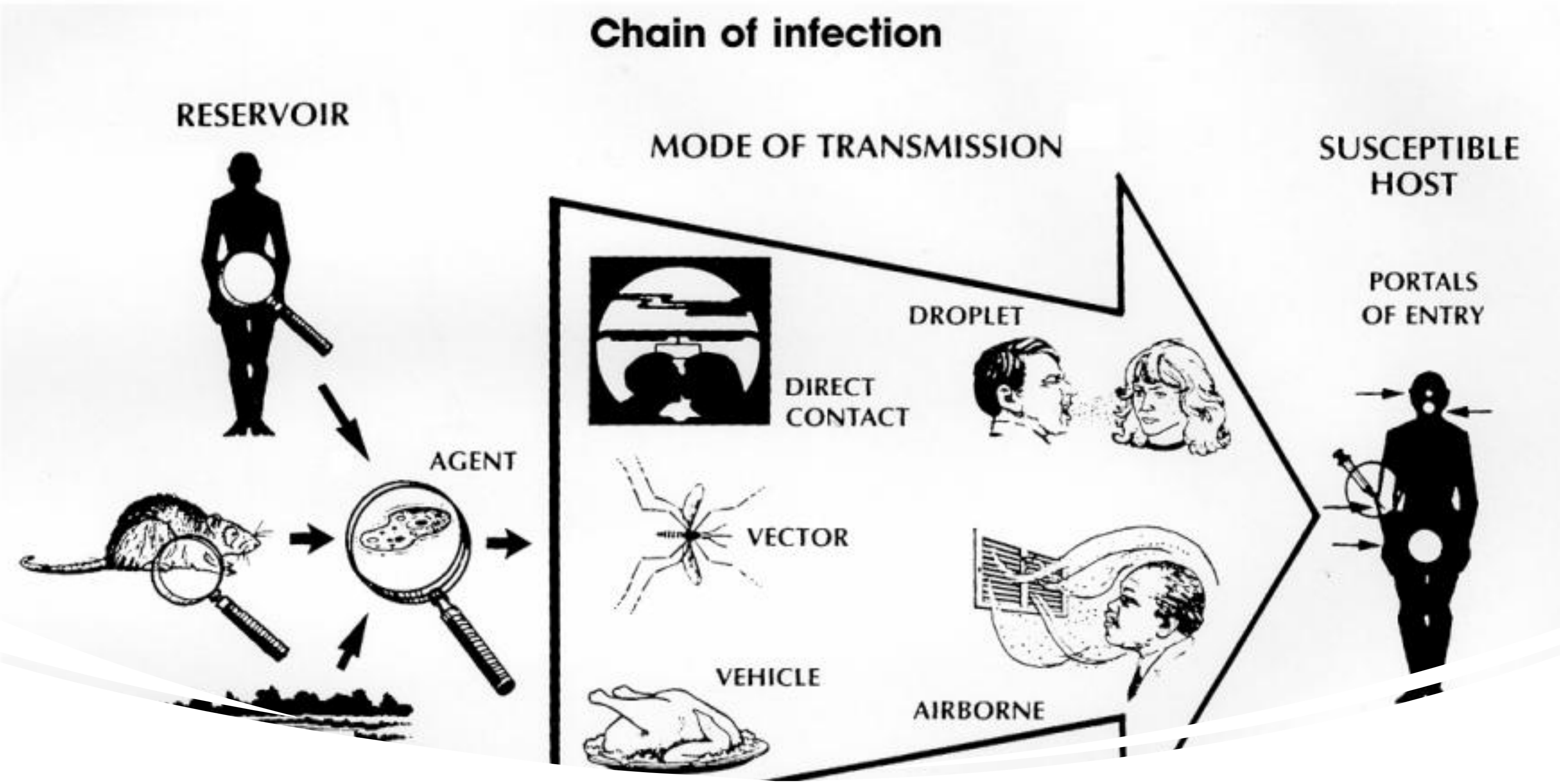
# OBJECTIVES

- **Mechanism of Airborne infections**
- **Hierarchy of Airborne infection controls**
- **Natural ventilation**
- **Mechanical ventilation**
- **Measurement of ventilation performance**




# INFECTION TRANSMISSION

- https://www.who.int/infection-prevention

# AIRBORNE VS DROPLET

| AIRBORNE INFECTIONS | DROPLET INFECTIONS |
| --- | --- |
| Particles < 5um size | Particles >5um size |
| Spread more than 3 feet distances | Spread less than 3 feet distances |
| Suspended for longer duration | Suspended for lesser duration |
| N95 respirator, mask,<br>Negative ventilation | Mask |
| Tuberculosis, Measles, etc. | Diphtheria, pertusis, etc. |



https://www.cdc.gov/csels/dsepd/ss1978/lesson1/section10.html

# Number of organisms released

Talking 0-200

Coughing 0-3,500

Sneezing 4,500- 1,000,000

# Size of the droplets

Sneeze ~3-10 m/s

75% are ~10 µm in diameter

< 25% are droplet nuclei (1-5 µm in diameter)

Wells 1955, Duguid 1945, Wells/Riley 1961, et al.

# WHAT TO DO?

# AIRBORNE INFECTION CONTROLS

## Managerial controls

- Develop a facility plan for airborne infection control

## Administrative controls

- Reduce potential opportunities for exposure

## Environmental controls

- Reduce concentration of infectious particles that may be present

## Personal respiratory protection

- Further reduce risk to staff (not other patients) in very high-risk settings where exposure not avoidable

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# ENVIRONMENTAL CONTROLS

- Indoor patient segregation and bed spacing
- Ensure **EFFECTIVE VENTILATION** at all times and seasons
  - **Ventilation is more effective if:**
  - Air flows from "clean" to "contaminated" (directional airflow)
  - There is good air-mixing (no stagnation or short circuiting)
- Special attention for high-risk areas
- Proper sitting arrangements

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# TYPES OF VENTILATION

**NATURAL VENTILATION**

**MECHANICAL VENTILATION**

**HYBRID VENTILATION**

- **3 Basic elements:**

**VENTILATION RATE**

**AIRFLOW DIRECTION**

**AIRFLOW PATTERN**

# CONCEPTS OF VENTILATION

- Ventilation moves outdoor air into a building or a room and distributes the air within the building or room.
- The general purpose of ventilation in buildings is to provide healthy air for breathing by both diluting the pollutants originating in the building and removing the pollutants from it.

**Building ventilation has three basic elements:**

1) **Ventilation rate :** the amount of outdoor air that is provided into the space and the quality of the out door air

2) **Airflow direction:** the airflow direction in a building which should be from clean zones to dirty zones and

3) **Air distribution or airflow pattern:** the external air should be delivered to each part of the space in an efficient manner and the airborne pollutants generated in each part of the space should also be transmitted in an efficient manner

# CONCEPTS OF VENTILATION

**ASSESSING VENTILATION PERFORMANCE**

- **Ventilation performance in buildings can be evaluated from the following four aspects, corresponding to the three basic elements of ventilation :**
  - Does the system provide sufficient ventilation rate as required?
  - Is the overall airflow direction in a building from clean to dirty zones (eg .isolation rooms, laboratory, containment areas,etc)
  - How efficient is the system in delivering the outdoor air to each location in the room
  - How efficient is the system in removing the airborne pollutants from each location in the room

# AIRFLOW DIRECTION

- Locate the health care worker (or other patients) near the clean air source
- Locate the person who may be infectious near a place where the air is exhausted away


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# CORRECT WORKING LOCATION


**Health care worker (HCW) is near the Clean air source**



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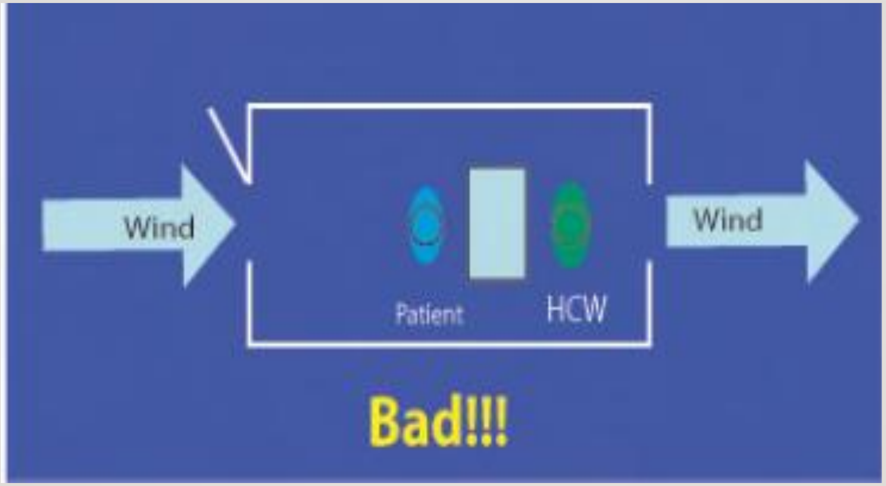
# INCORRECT WORKING LOCATION




**Resolve by switching places so the health care worker is near the clean air source**

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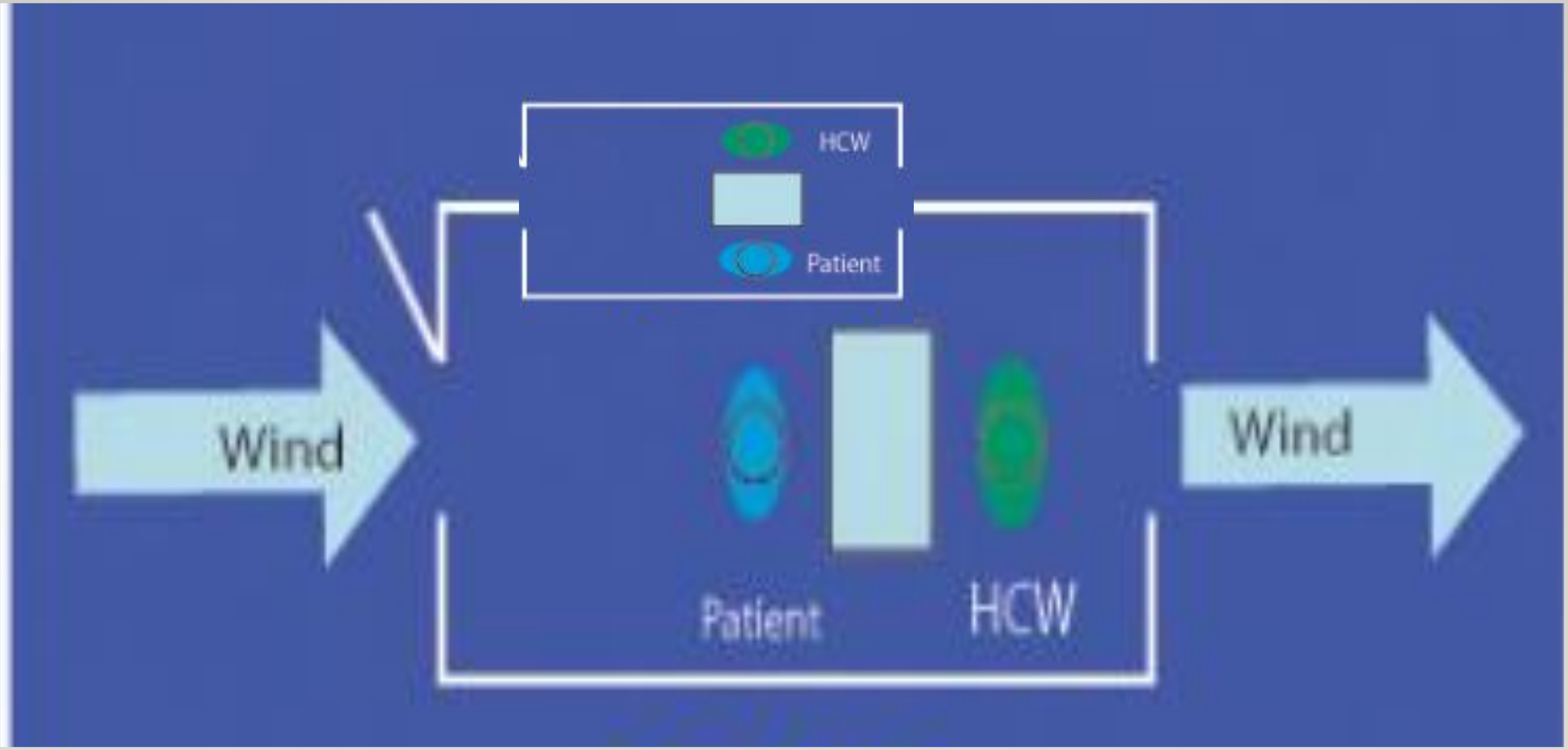
# GOOD COMPROMISE

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Poorly-installed exhaust fan in an open window space, with "short-circuiting" of air-flow.

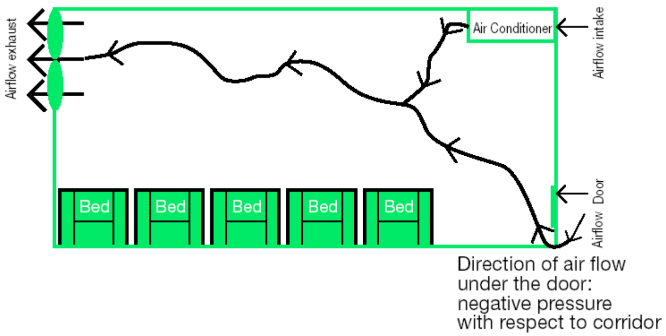
# DIRECTIONAL CONTROL OF AIR-FLOW

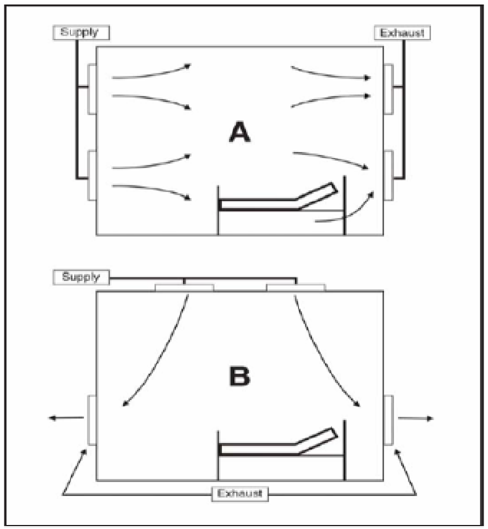
➢Directional control of air flow

(i.e, negative pressure) is recommended

<u>in specific high-risk settings</u> where infectious patients with drug-resistant TB or other acute respiratory diseases of potential concern are likely to be managed

i.e. airborne isolation rooms, MDR-TB wards and clinics, and bronchoscopy suites



# NATURAL VENTILATION

Created by the use of external airflows generated by natural forces such as:

- **Flow of Wind**
- **Differences in temperature**

Naturally ventilated rooms can achieve very high ventilation rates (ACH) under ideal conditions

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# Types of natural ventilation

## Stack effect (buoyancy)

- Warm air is lighter (less dense) than cold air
- Warm air rises, cold air falls
- Intentional chimneys (stacks) can create larger differences between top and bottom, increasing the air flow rate

## Wind-driven (pressure)

- Pressure differences result in air mass movement
- “Packets” of air flow from higher to lower air pressure regimes


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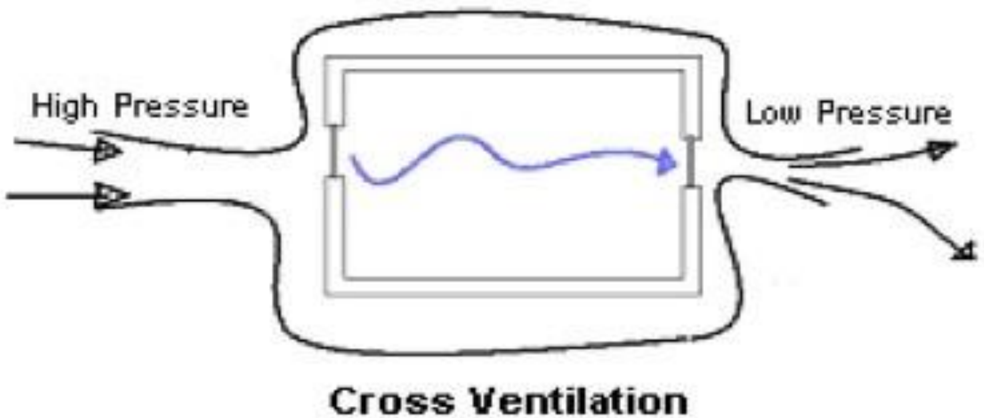
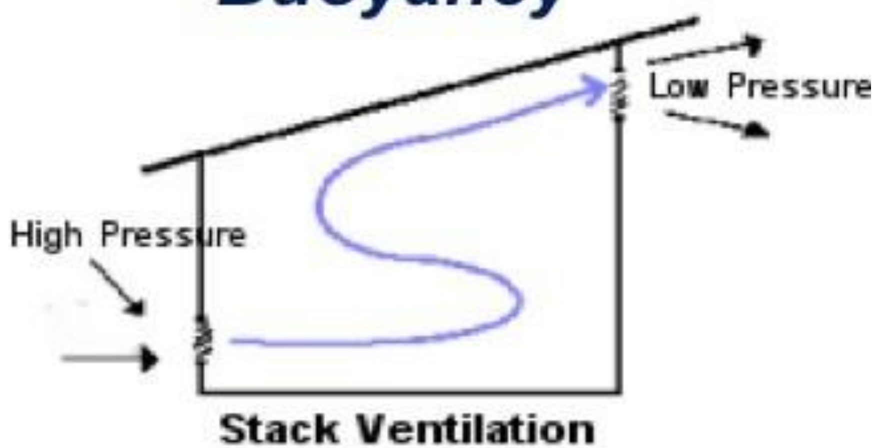
# Wind driven vs. Stack effect




***Wind driven***

***Buoyancy***

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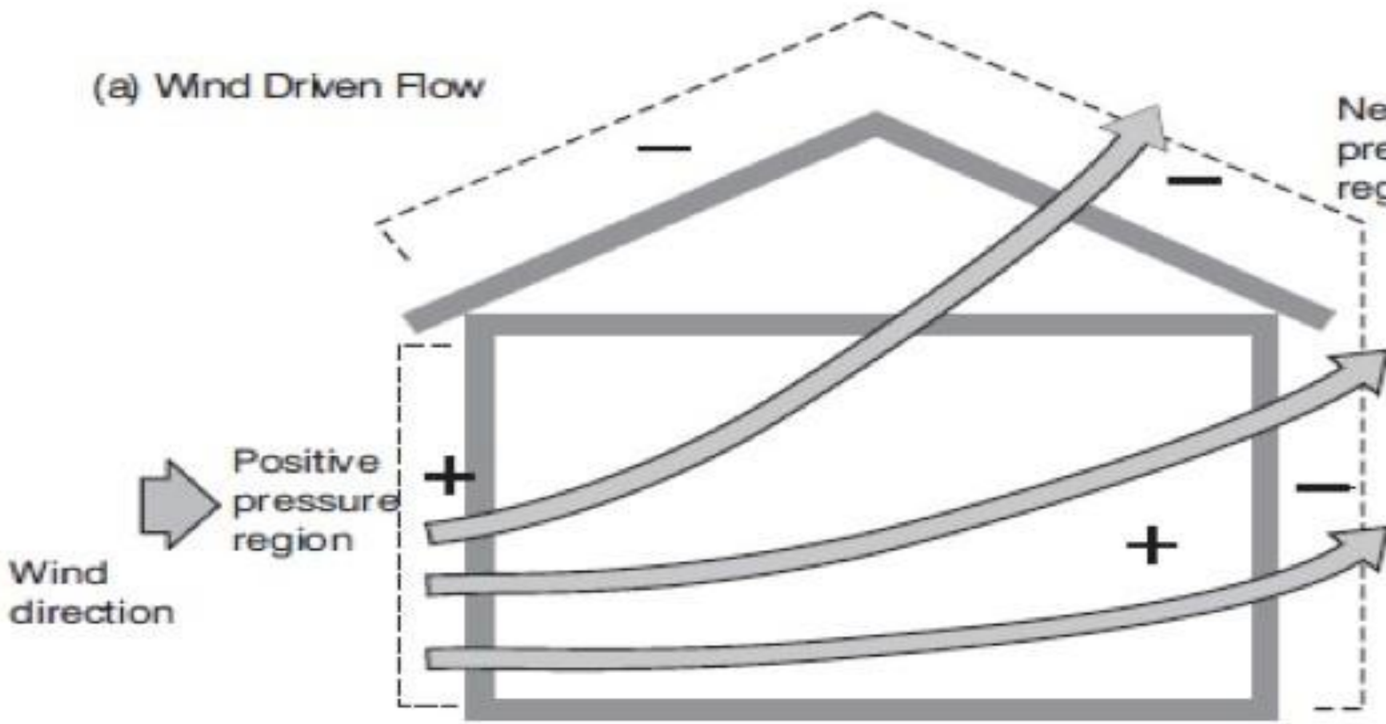
# Natural Driving Mechanisms – Pressure: Wind-driven air flow

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# Stack Effect

The efficiency of solar chimneys can be improved by:

- Increasing the stack height.
- Increasing the temperature difference between collector and ambient air.

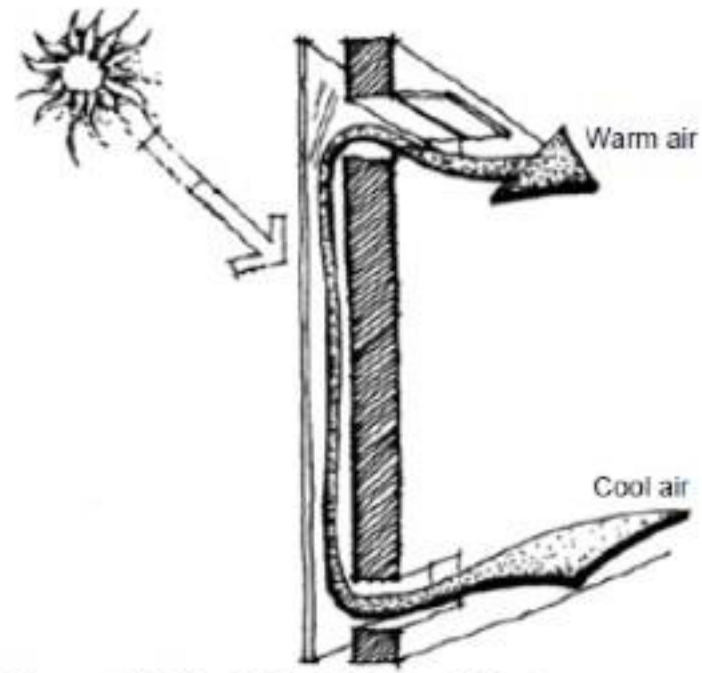


Figure 4. The Solar Chimney Effect

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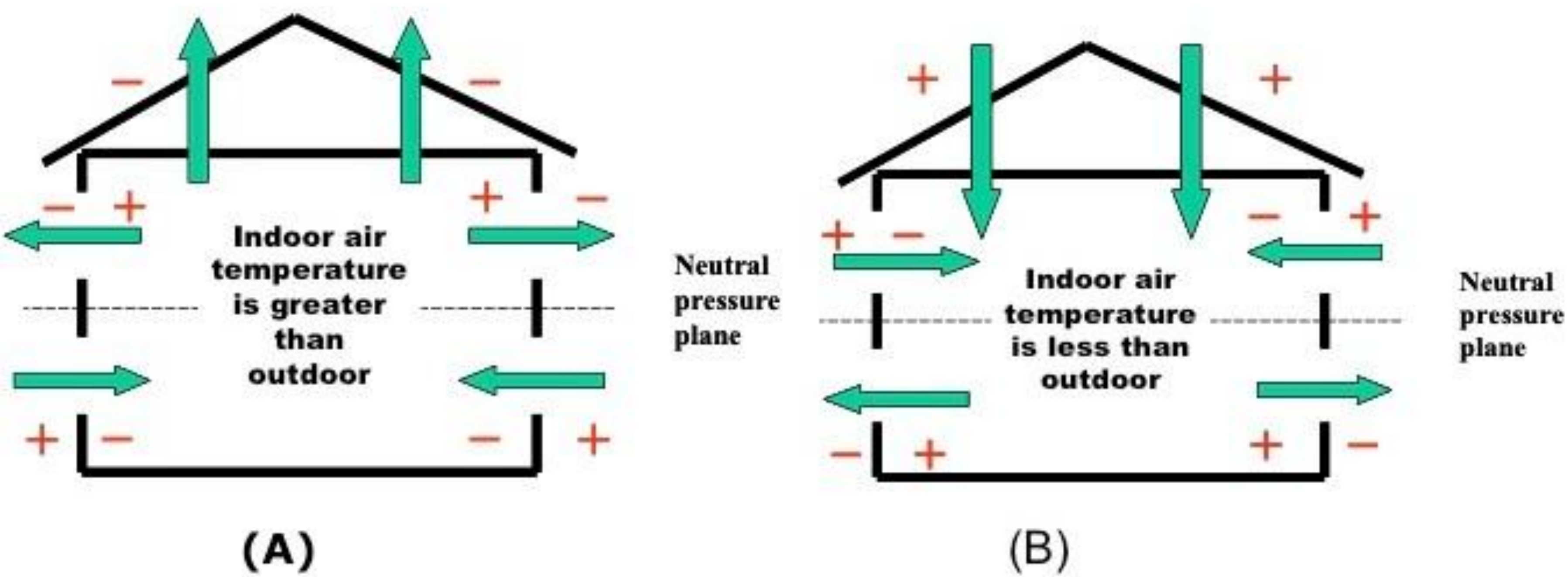
# Stack driving flows in a building




*Indoor air warmer than outdoor*

*Indoor air cooler than outdoor*



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# BRE's Environmental Office Building

- *Low energy fans for use on still air days*
- *Glass for solar heating of thermal chimney*

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# NATURAL VENTILATION

- In most settings, natural ventilation is the preferred method for ensuring adequate air exchange.

- Ensure *effective* ventilation at all times and in all climatic conditions through proper operation and maintenance, and by regular checks to ensure fixed, unrestricted openings.

Example: Use of louvered shutters instead of glass windows to ensure ventilation day and night



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# NATURAL VENTILATION

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# TURBINE DRIVEN VENTILATION


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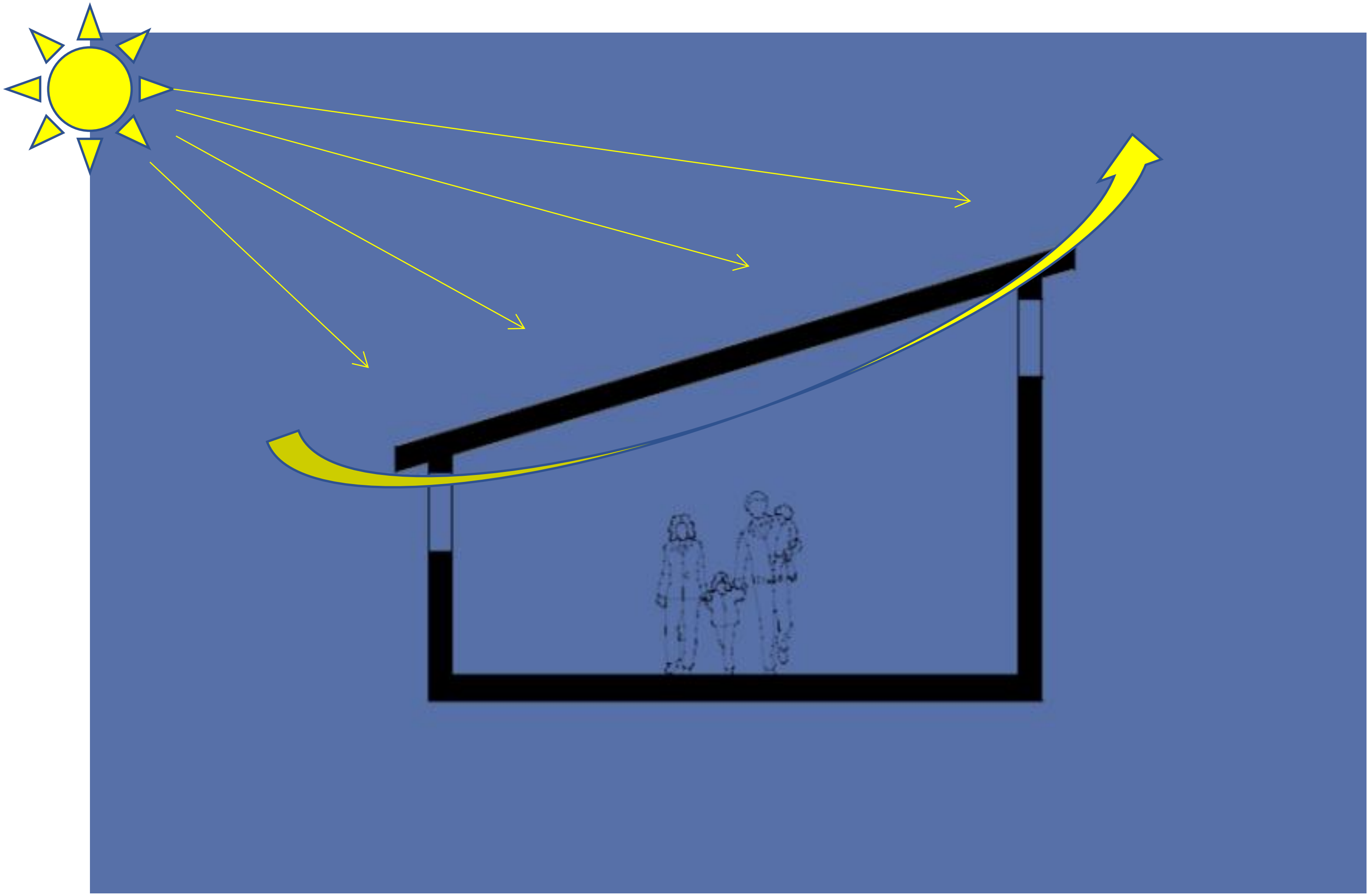
# STACK VENTILATION



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# MAXIMIZE NATURAL VENTILATION

*Where ACH is not able to be measured, as is usually the case in rooms with natural ventilation*, the following standards for ventilation should be followed to ensure that air exchange is safely >6 ACH under all climactic conditions.

- Openings on opposite walls (cross ventilation)
- Openings are unrestricted (stay open)
- 20% of floor space should be openable window area on each wall
- Upper levels of the building (higher from the ground floor)
- Building and openings are oriented to use the prevailing wind, without obstruction by other nearby buildings

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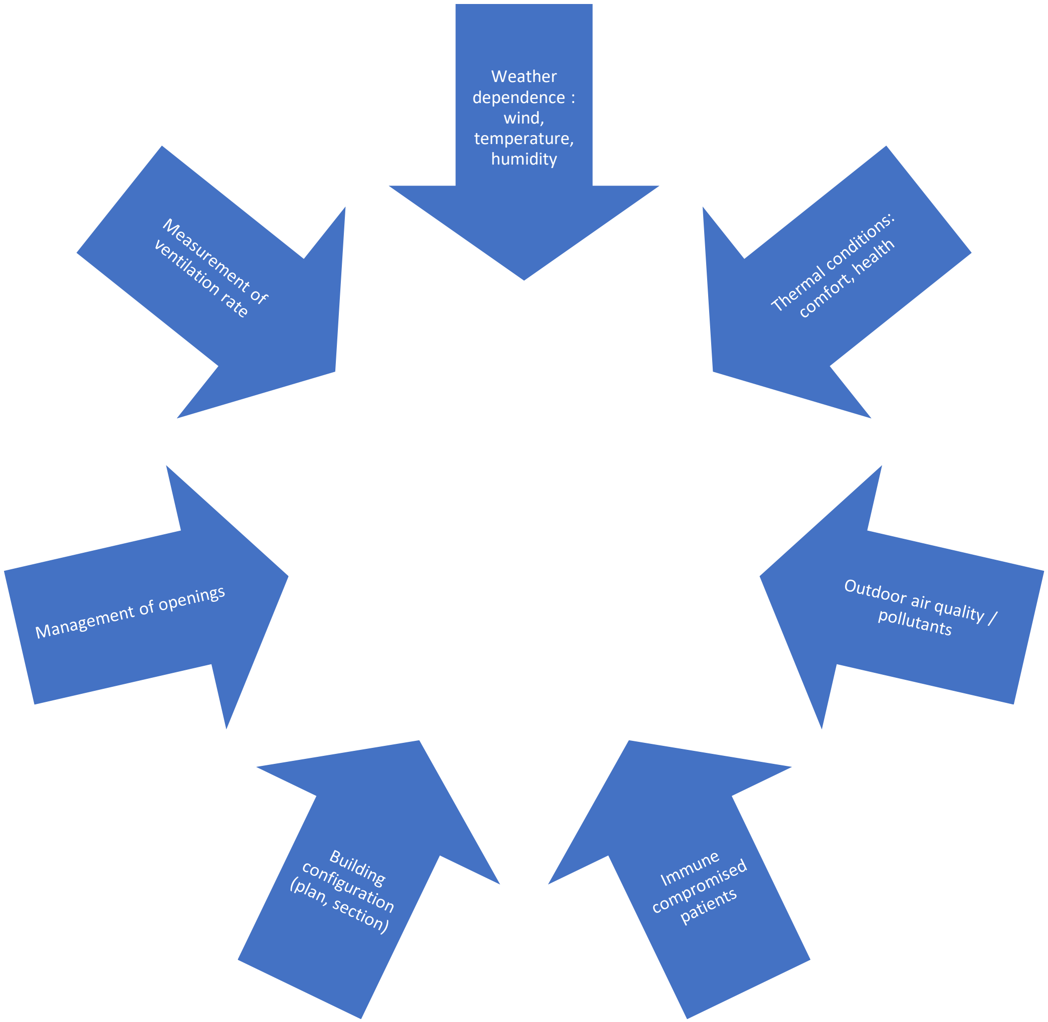
# NATURAL VENTILATION ISSUES

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# AIR CHANGES PER HOUR (ACH)

CALCULATING ACH IS THE MOST SIMPLE WAY TO ASSESS VENTILATION

ACH = VOLUME OF AIR MOVED IN ONE HOUR

ONE ACH MEANS THAT THE VOLUME OF AIR IN THE ROOM IS REPLACED IN ONE HOUR

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# AIR-CHANGES PER HOUR (ACH) REQUIRED

| Type of Health care setting | Minimum ACH |
|---|---|
| Registration/Waiting | ≥ 6 ACH |
| Outpatient departments | ≥ 6 ACH |
| Inpatient departments | ≥ 6 ACH |
| High-risk settings<br>ART centres<br>TB / Chest departments (outpatient and inpatient)<br>Bronchoscopy procedure rooms<br>MDR-TB wards and clinics<br>Airborne isolation rooms | ≥ 12 ACH |

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# TIME REQUIRED FOR REMOVAL OF DROPLET NUCLEI

| ACH | 99% | 99.9% |
|---|---|---|
| 2 | 138 minutes | 207 minutes |
| 4 | 69 | 104 |
| 6 | 46 | 69 |
| 12 | 23 | 35 |
| 15 | 18 | 28 |
| 20 | 14 | 21 |
| 50 | 6 | 8 |
| 400 | <1 | 1 |



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# MEASUREMENT OF AIR VELOCITY


*Never put fingers on the open space of the vaneometer*

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# MEASURE DIMENSIONS OF THE AREA

**AREA OF WINDOW OPENING = LENGTH X WIDTH**

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# CALCULATE ROOM VOLUME

**ROOM VOLUME = WIDTH X DEPTH X HEIGHT**

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# ACH CALCULATION

- Window area = length x width
- Air velocity through window using vaneometer
- Air flow rate  = window area x air velocity
- Room volume = width x depth x height = 45 $m^3$
- **ACH = Air flow rate divided by room volume**

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# WHAT'S WRONG WITH THIS PICTURE?


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# WHAT'S WRONG WITH THIS PICTURE?

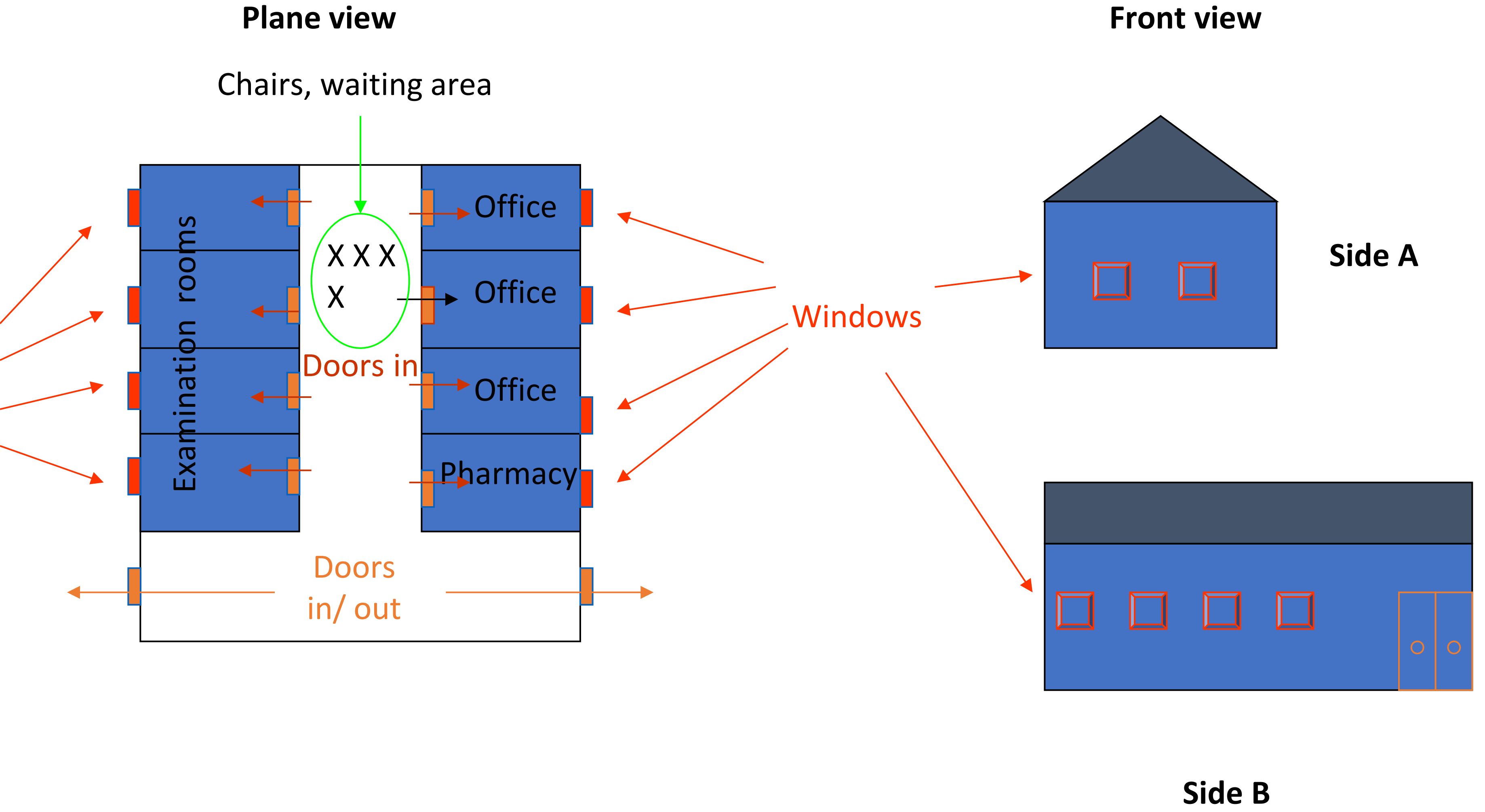

Very poor ventilation, blocked windows, re-circulating A/C

Ineffective filtration devices gives false security

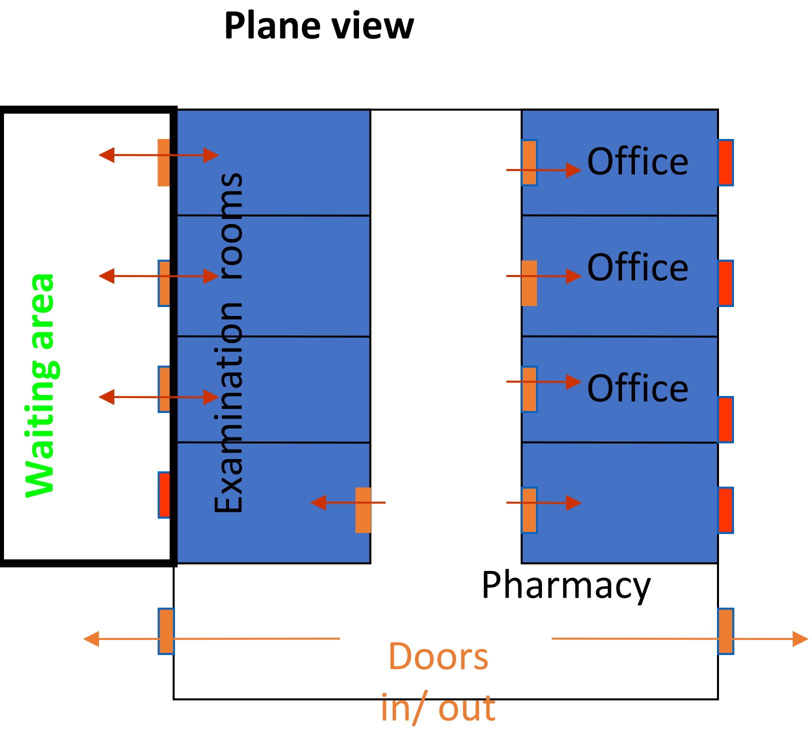
Exhaust fan would draw air from waiting to doctor's chamber

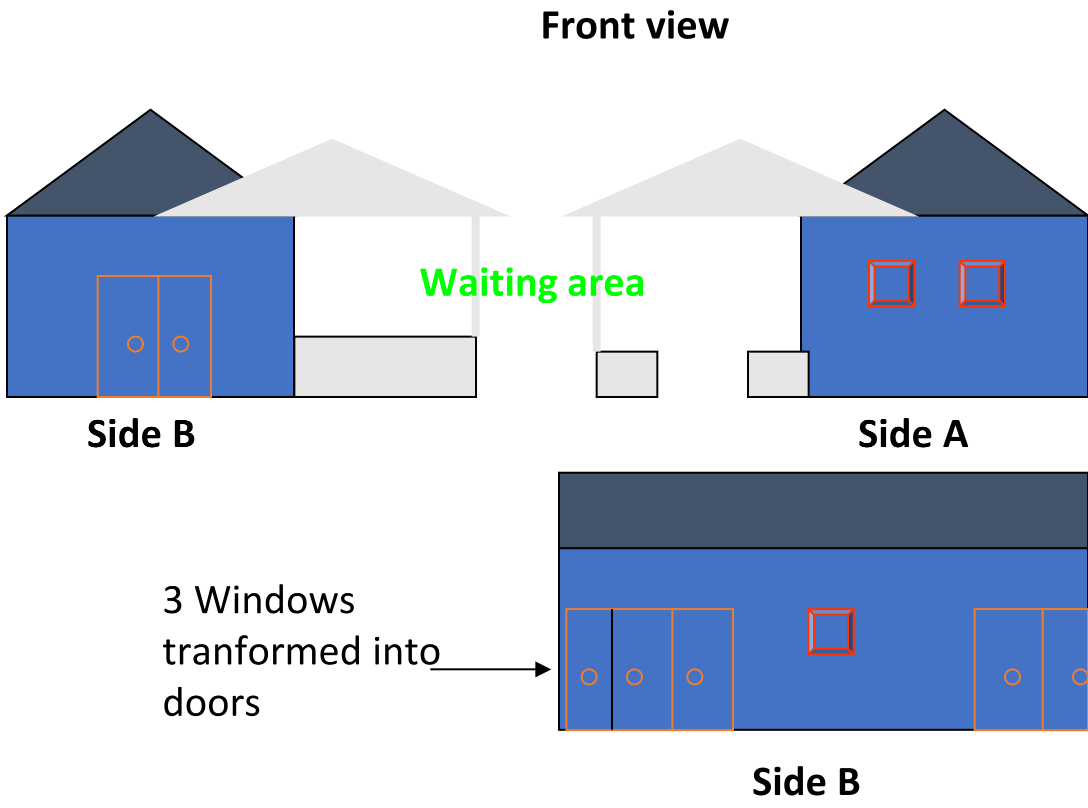
Crowded waiting area (wait outside!)

# POORLY VENTILATED WAITING AREA IN AN OUT-PATIENT CLINIC



# WAITING AREA
# MAXIMIZING NATURAL VENTILATION



# MECHANICAL VENTILATION

- **Mechanical ventilation  with or without climate control :**

  May be appropriate *where natural ventilation cannot be implemented effectively or is inadequate* given local conditions (e.g. building structure, climate, regulations, culture, cost and outdoor air quality)

- If mechanical ventilation is used, the system *should be well designed, maintained and operated*, to achieve adequate airflow rates and ***FRESH*** air exchange.



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# HEPA FILTRATION

**Must be used**

- **When discharging air from local exhaust ventilation booths or enclosures directly into the surrounding room, and**
- **When discharging air from an Airborne infection isolation room into the general ventilation system**



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# ULTRAVIOLET GERMICIDAL IRRADIATION (UVGI)

- In high-risk settings where it is *not possible* to achieve adequate air exchange using natural ventilation, a complementary option is to use upper room or shielded ultraviolet germicidal irradiation (UVGI) devices.

- Installation should seek to *irradiate the maximal air volume with the highest intensity UV*, while keeping staff and patient exposure to less than 6.0 mg/cm2 over an 8-hour period.

- Emphasis on proper installation and maintenance.

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# ADVANTAGES OF VARIOUS VENTILATION METHODS

| MECHANICAL VENTILATION | NATURAL VENTILATION | HYBRID VENTILATION |
|---|---|---|
| Suitable for all climates and weather with air-conditioning gas climate dictates | Suitable for warm and temperature climates- moderately useful with natural ventilation possible 50 % of the time | Suitable for most climates and weather |
| More controlled and comfortable environment | Lower capital, operational and maintenance costs for simple natural ventilation | Energy saving |
| Smaller range of control of environment by occupants | Capable of achieving high ventilation rate<br>Large range of control of environment by occupants | More flexible |

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# SUMMARY

## AIR CHANGE RATE:

- Ensure adequate average flow and minimum flow specification are met
- Approximate measurements under all weather and building operational conditions
- Measurements, Verification

## AIR DISTRIBUTION:

- **Flow direction**
  - Away from infected- verify
  - Ensure and verify consistency under all seasons
- Flow of infectious agents directly out of building /facility
- Avoid flow toward other patients, especially susceptibles

## MANAGEMENT PLAN

# YOUR PATIENT HAS ENTRUSTED HIS LIFE

# IN YOUR HANDS