Anaesthetic breathing systems

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Introduction

- 3 main functions
  - Delivery of anaesthetic gases and vapours
  - Oxygenation of the patient
  - Removal of carbon dioxide
- Several different classifications exist
Properties of the ideal breathing system

- Simple and safe to use
- Delivers intended inspired gas mixture
- Permits spontaneous, manual & controlled in all ages
- Efficient, requiring low flow rates
- Protects patients from barotrauma
- Sturdy, compact and lightweight
- Easy removal of waste exhaled gases
- Easy to maintain with minimal running costs
# Old classification

<table>
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<tr>
<th>Type</th>
<th>Description</th>
<th>System</th>
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Schimmelbusch mask
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Mapleson systems

Mapleson A

Mapleson B

Mapleson C

Mapleson D

Mapleson E

"Mapleson F"

FG = Fresh gas  P = Patient
## Old classification

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<tr>
<th>Classification</th>
<th>Boundary Description</th>
<th>Equipment/Explanations</th>
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Circle system
Modern classification

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<th>Systems with potential for rebreathing</th>
<th>Bidirectional flow within the system</th>
<th>Mapleson classification</th>
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<td>Unidirectional flow with valves</td>
<td>Drawover systems and resuscitation bags</td>
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<td>Carbon dioxide absorption</td>
<td>Circle systems and ‘to and fro’ systems</td>
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Components of a breathing system

- Adjustable pressure-limiting valve
- Reservoir bag
- Tubing
Adjustable pressure-limiting valve

- Spill valve, pop-off valve, expiratory valve, relief valve
- Designed to vent gas during positive pressure
- Pressure of less than 0.1 kPa activates the valve when open
Components

- 3 ports: inlet, patient and exhaust port - latter can be open to atmosphere or connected to the scavenging system
- Lightweight disc sits on a knife-edge seating - held in place by a spring
- Tension in the spring and therefore the valve’s opening pressure is controlled by the valve dial
Mechanism of action

- One-way, adjustable, spring-loaded valve
- Valve allows gases to escape when the pressure in the breathing system exceeds the valve’s opening pressure
- During spontaneous ventilation, the patient generates a positive pressure during expiration, causing the valve to open
- During positive pressure ventilation, a controlled leak is produced in inspiration by adjusting the valve dial, allowing control of the patient’s airway pressure
Problems in practice and safety features

- Malfunction of scavenging system can cause excessive negative pressure which can lead to the APL valve being open throughout respiration.

- The patient can be exposed to excessive positive pressure if the valve is shut during assisted ventilation—safety mechanism actuated at 6 kPa in some designs.

- Water vapour in exhaled gas may condense on the valve—disc made of hydrophobic material which prevents water condensing.
Reservoir bag

- Antistatic rubber or plastic
- Ellipsoid in shape
- Standard adult size is 2 l (range from 0.5 to 6 l)
Mechanism of action

- Accommodates fresh gas flow during expiration acting as a reservoir available for the following inspiration
- Acts as a monitor of patient’s ventilatory pattern during spontaneous breathing and also a very inaccurate guide to tidal volume
- Used to assist or control ventilation
Problems in practice and safety features

- Because of its compliance, the reservoir bag can accommodate rises in pressure in the breathing system.
- Limits the pressure in the system to about 4 kPa.
- Size of the bag depends on breathing system and patient.
- If too small may not provide a large enough reservoir for big tidal volumes.
- If too large, does not act as respiratory monitor.
Tubing

- Corrugated or smooth
- Different lengths depending on system being used
- Allow humidification of inspired air
- Parallel and coaxial arrangements available
Mapleson classification

- Mapleson classified breathing systems in 1954 into 5 types (later modified to include the Rees modification)
- Efficiency: fresh gas flow required to prevent rebreathing
- Rebreathing:
  - Rebreathing expired air including carbon dioxide
  - Recirculation of expired gas with carbon dioxide removed and oxygen added
Mapleson classification

Mapleson A

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Mapleson A

- Corrugated rubber or plastic tubing: 110-130 cm in length
- Reservoir bag at machine end
- APL valve at the patient end
Mechanism of action

- As patient exhales, dead space gas is channelled towards reservoir bag which is continuously filled with fresh gas
- Pressure builds, opening APL valve and expelling alveolar gases
- The patient inspires, getting a mixture of fresh gas and dead space gases
- Efficient for spontaneous breathing: FGF required to prevent rebreathing = patient’s minute volume (70 ml/kg/min)
- Not efficient for controlled ventilation: FGF required to prevent rebreathing = \(x2-3\) minute volume
Mechanism of action

Figure 2: Mode of action of Magill attachment during spontaneous ventilation
Problems in practice and safety features

- Not suitable for children less than 30 kg due to increased dead space at patient end

- Heaviness of APL valve at patient end puts a lot of drag on the connections especially if connected to scavenging system
Mapleson A- Lack system

- Coaxial modification of Magill Mapleson A
- 1.8 m length
- FGF through outside tube, exhaled gases through inner tube
- Inner tube wide in diameter (14 mm) to reduce resistance to expiration
- Reservoir bag at machine end
- APL valve at machine end eliminating drag at the patient end
Mapleson B and C

- Components
  - Reservoir bag
  - APL valve at patient end
  - FGF proximal to APL valve

- Not efficient for spontaneous ventilation (FGF of x1.5-2 MV required to prevent rebreathing)

- During controlled ventilation, B system more efficient as tubing acts as reservoir (FGF > 50% still required to prevent rebreathing)
Mapleson D- Bain circuit

- Coaxial and parallel versions available (180 cm)
- FGF through inner tube, exhaled gas through outer tube
- Reservoir bag at machine end
- APL valve at machine end
Mechanism of action

- During spontaneous ventilation, patient’s exhaled gases are channelled back to the bag and mixed with FGF.
- Pressure build up opens the APL valve allowing venting of this mixture of gases.
- FGF required to prevent rebreathing is about 150-200 ml/kg/min.
- Inefficient for spontaneous ventilation.
- More efficient for controlled ventilation.
- FGF of 70 ml/kg/min.
Mechanism of action

![Diagram of the mode of action of a Mapleson D breathing system during spontaneous ventilation.](image-url)
Problems in practice and safety features

- Internal tube can kink preventing FGF to the patient
- Internal tube can become disconnected at the machine causing a huge increase in dead space resulting in hypoxaemia and hypercapnia
- Movement of the reservoir bag is not always an indication that fresh gas is being delivered to the patient
Mapleson E and F

- Valveless breathing system used for children upto 30 kg
- Suitable for spontaneous and controlled ventilation
- Components
  - T shaped tubing with 3 ports
  - FGF delivered to one port
  - 2nd port goes to patient
  - 3rd port leads to reservoir tubing (Jackson-Rees modification)
Mechanism of action

- Requires a FGF of x2-3 minute volume to prevent rebreathing (minimum flow 4 l/min)
- Double-ended bag acts as a monitor for ventilation
- Bag can be used for assisted or controlled ventilation and CPAP during spontaneous ventilation
- Volume of the reservoir tubing determines degree of rebreathing (too large a tube) or entrainment of room air (too small a tube)
- Volume of reservoir bag should be about patient’s tidal volume
Problems in practice and safety features

- No APL valve so scavenging can be a problem
- High flows required to prevent rebreathing
- Double-ended bag allows CPAP (particularly useful in children under 6 years of age as they have a low FRC)
Topics to look up

- Checking circuits - Bain’s
- Circle circuits
  - Components of a circle circuit
  - Draw a circle circuit
- Humphrey ADE breathing system
- Drawover systems