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

Open	No boundary and no dead space	Oxygen tubing near patient
Semi-open	Partial boundary between airway and atmosphere	Schimmelbusch mask
Semi-closed	Fully bounded. Prevents entry of atmospheric air but vents excess fresh gas	Mapleson systems
Closed	No venting of excess gas	Circle systems at low flows

Schimmelbusch mask

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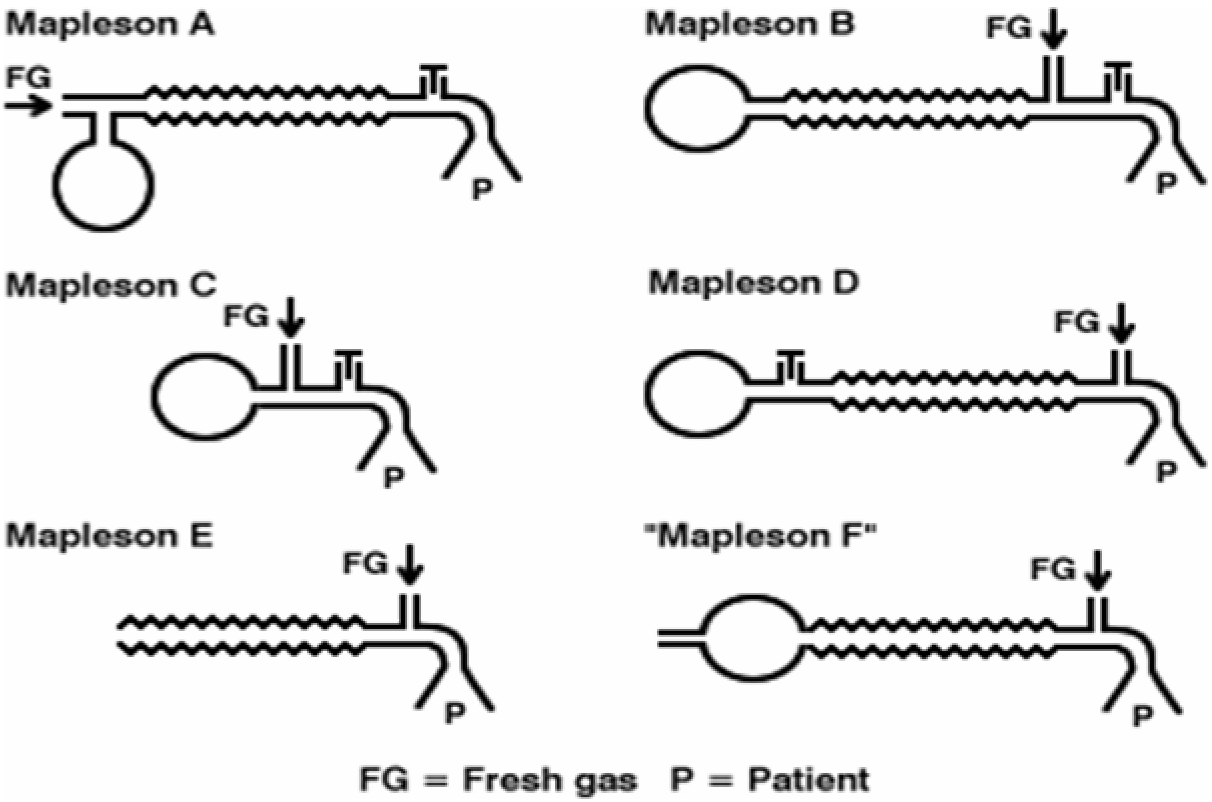
Mapleson systems



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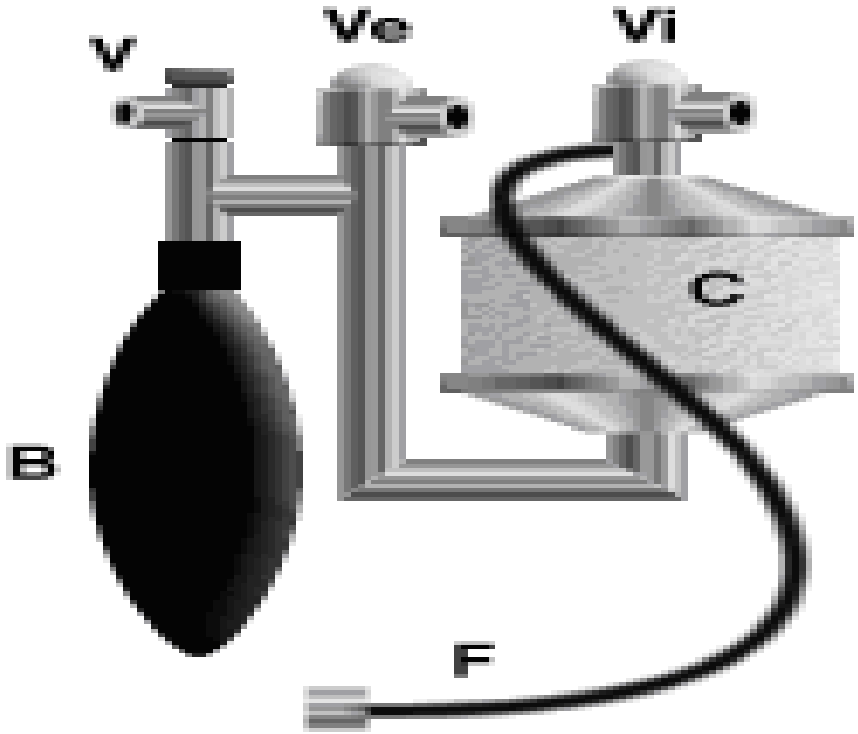
Circle system



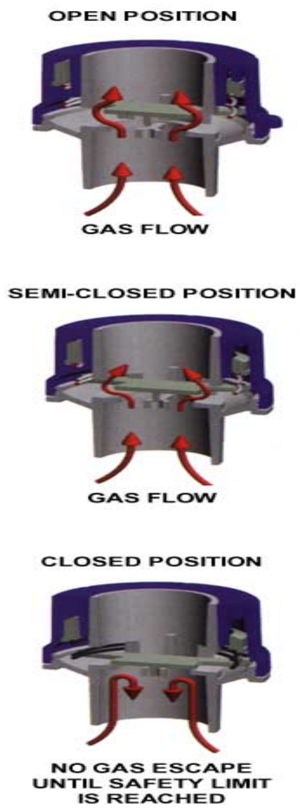
Modern classification

Systems with potential for rebreathing	Bidirectional flow within the system	Mapleson classification
Non-rebreathing systems	Unidirectional flow with valves Carbon dioxide absorption	Drawover systems and resuscitation bags Circle systems and ‘to and fro’ systems

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

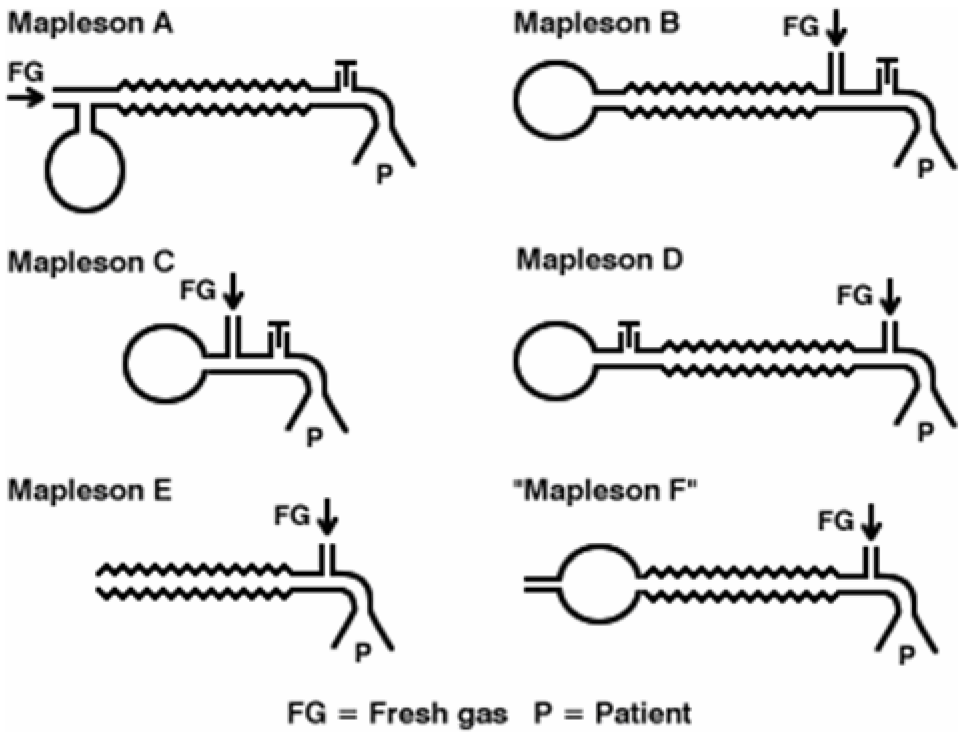
Tubing

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

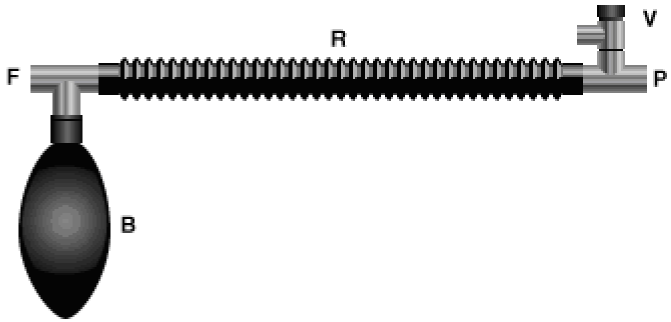
Mapleson classification

- 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



- 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

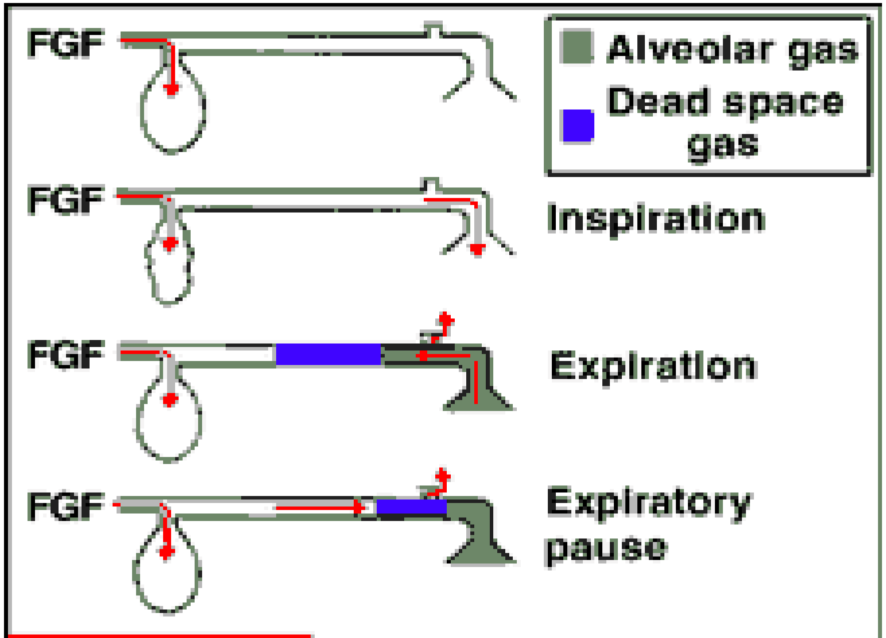
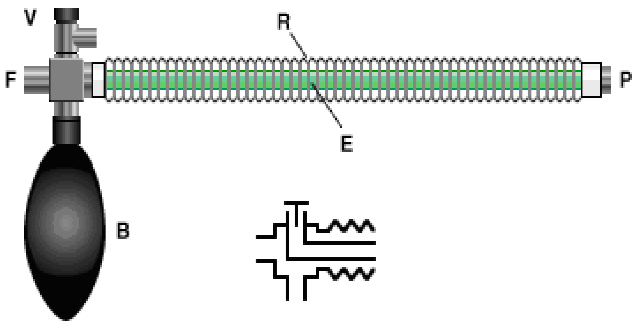


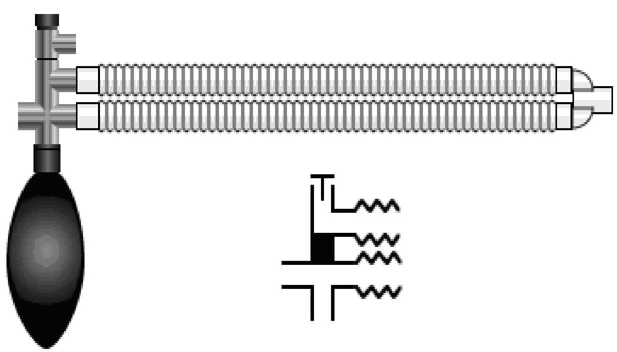
Figure 2 Mode of action of Magill attachment during spontaneous ventilation

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

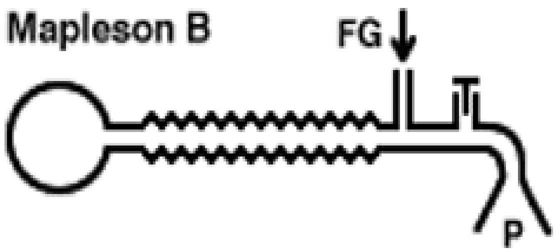
Mapleson A- Lack system

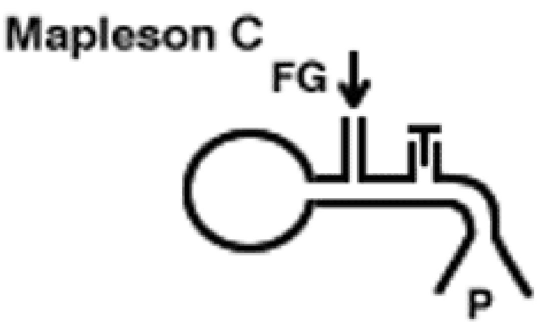




- Coaxial modification of Magill Mapleson A
- 1.8 m length
- FGF through outside tube, exhaled gases through inner tube
- Inner tube wide in diameter (14 mm) to reduce resistance to expiration
- Reservoir bag at machine end
- APL valve at machine end eliminating drag at the patient end

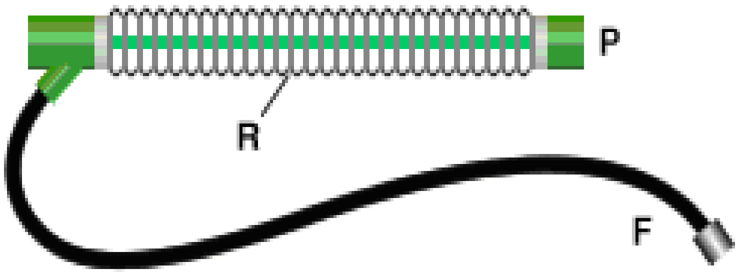
Mapleson B and C

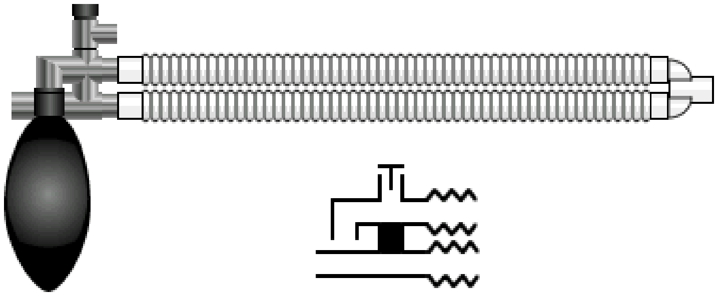




- Components
  - Reservoir bag
  - APL valve at patient end
  - FGF proximal to APL valve
- Not efficient for spontaneous ventilation (FGF of x1.5-2 MV required to prevent rebreathing)
- During controlled ventilation, B system more efficient as tubing acts as reservoir (FGF > 50% still required to prevent rebreathing)

Mapleson D- Bain circuit



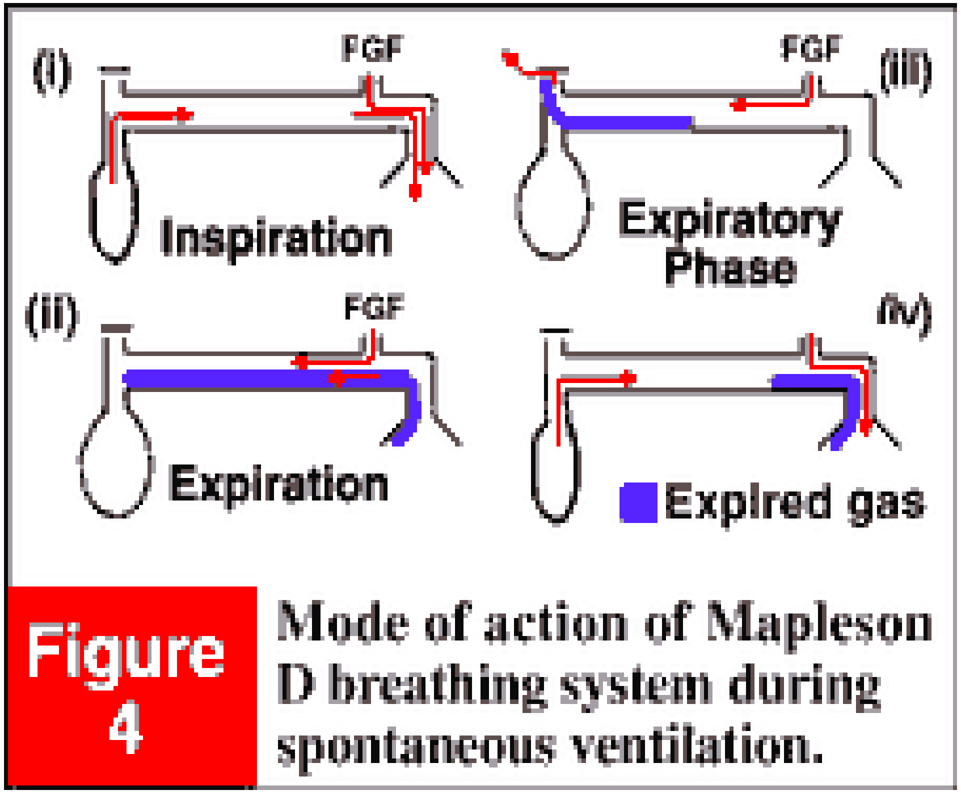


- Coaxial and parallel versions available (180 cm)
- FGF through inner tube, exhaled gas through outer tube
- Reservoir bag at machine end
- APL valve at machine end

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 allows 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

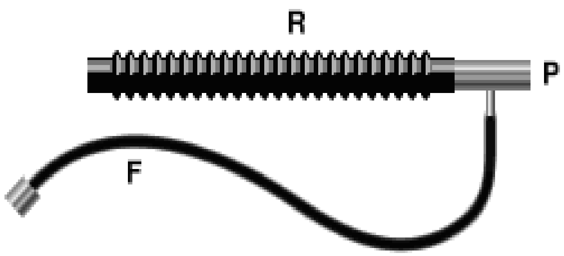


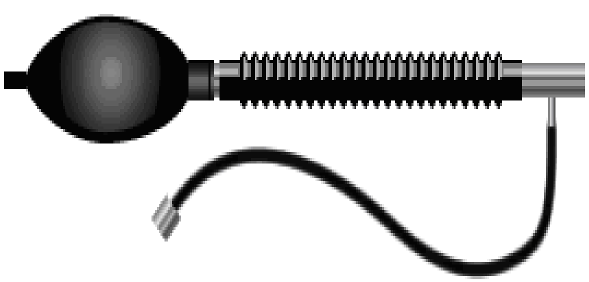
Mode of action of Mapleson D breathing system during spontaneous ventilation.

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