The anaesthetic breathing system lies between the anaesthetic machine and the endotracheal tube or face mask. Its purpose is to deliver oxygen and volatile gas to the patient, to remove waste gases and to provide a method of ventilation as necessary.

It is made up of multiple components which include:

- **Fresh gas outlet**
  This connects the breathing system to the anaesthetic machine

- **Breathing tubes**
  These allow gas to travel to and from the patient

- **Reservoir bag**
  This allows for visualisation of respiration, accumulation of oxygen and anaesthetic gases and provide a method of ventilation.

- **Adjustable pressure limiting (APL) valve**
  Allows for safe connection to scavenging, releases waste gases, allows for control over and limits pressure build up

- **Scavenging**
  Safe removal of anaesthetic gases

- **Unidirectional valves.**
  Ensures gases flow the correct way and prevents fresh gas from mixing with waste gases.

- **Carbon dioxide absorbent**
  Its purpose is to absorb expired carbon dioxide which then allows for complete rebreathing of exhaled gases.

Breathing systems can be generally classified into open, semi open, semi closed and completely closed. In an open system the air can enter the respiratory tract during inspiration; there is no reservoir for the gases and no scavenging so carbon dioxide is removed by dilution. This method includes the chlorophol cloth or mask over the patient’s face and is not used in modern veterinary anaesthesia.

A semi open system is what can be classified as a non-rebreathing system. A semi-closed system is a rebreathing system and therefore must have carbon dioxide absorbent and scavenging. Because it is semi-closed it also required a fresh gas input. This method is the most popular method of using a rebreathing system.

A closed system must have carbon dioxide absorbent but does not have scavenging or fresh gas whilst it is being used as a closed system. All the gas is completely recycled and stays entirely between the patient and the breathing system. A closed system is most typically used when it is required that an anaesthetised patient is moved any distance and means of keeping them anaesthetised are required. This way the breathing system,
and therefore the anaesthetic gases stay with the patient as they move preventing early recovery, or hypoxia.

Non-rebreathing systems are simple systems with minimal apparatus dead space. This means they have low resistance making them ideal for smaller patients. Nitrous oxide can be used safely in all non-rebreathing systems (although not all patients) and the inspired concentration should be similar to vaporiser setting. They are also more affordable that re-breathing systems to buy and maintain. Unfortunately they are not very economical and can be wasteful as they require high fresh gas flow rates. They are classified by the Mapleson system, from A-F according to their efficiency. This is dependent upon their components & which position they take in the breathing system.

Mapleson divided them mainly into afferent reservoir system & efferent reservoir systems.

**Mapleson A**
- The Mapleson A is commonly known as the Magill breathing system.
- It consists of reservoir bag adjacent to fresh gas inlet, an APL valve and breathing tubes.
- It has a circuit factor 1-1.5
- It is not ideal for IPPV as it requires high FGF for this.
- It is suitable for patients over 10kgs
Unfortunately because of the high fresh gas flow rates required for IPPV it highly inefficient during manual ventilation.

- The high FGF rates are required to prevent build-up of waste gases in reservoir bag & tubing.
- However, this does also mean that it a very efficient and economic breathing system during spontaneous respiration which is simple to use.
- The lack also comes under classification A of Mapleson’s system.

- This is because its reservoir bag is on the inspiratory limb meaning it has a circuit factor of 1-1.5.
- This means that the lack too is not suitable for IPPV as the fresh gas flow rate would need to be 3 times the minute volume.
- Although the APL valve is located much more conveniently for IPPV is manual ventilation is required in an emergency situation.
- It comes in several forms to suit the user – coaxial or parallel and miniature or standard.
- The miniature lack can be used on patients from 2-12kgs while the standard lack is suitable for patients over 10kgs.
- Just like the Magill it is simple, efficient and economical to use during spontaneous respiration.
- Unfortunately the lack has more tubing than the Magil, therefore adding extra volume and resistance.

The Mapleson A functions in the follow way; during inspiration the spill valve closes allowing fresh gas to be inspired by the patient. During expiration the exhaled gas is met by the continuous flow of fresh gas which drives the exhaled gas into the expiratory tube and out of the valve into scavenging. During the inspiratory pause, fresh gas fills the reservoir bag and inspiratory limb, flushing away any remaining waste gas, ready for the next breath.
**Mapleson B**
Breathing systems classified as Mapleson B have the fresh gas inlet near the patient. The expiratory valve only opens when the pressure is high which results in a mixture of waste and fresh gas. It would require very high fresh gas flow rates to minimalize any rebreathing. As a result it is not suitable for anaesthesia.

During inspiration the spill valve closes allowing for inspiration of fresh gas. When the patient expires the breathing tubes and reservoir bag are filled with waste gas. The filling of the reservoir bag causes a high positive pressure which allows the valve to open. During the expiratory pause the fresh gas flushes the waste gas to scavenging and fills the breathing tube and reservoir bag, however very high fresh gas flow rates are required for this to work.

**Mapleson C**
The Mapleson C is very similar to the Mapleson B classification. It requires very high FGF rates and is not suitable for anaesthesia. Its function is the same as the Mapleson B.

**Mapleson E**
The Ayres T-piece is classified as Mapleson E. It has no APL valve, no active scavenging, no reservoir bag and requires high FGF rates as it has a circuit factor of 2.5-3. Due to the absence of reservoir bag it is not suitable for IPPV, however it has little resistance owing to its simplicity and minimal components. This makes it suitable for any patient under 10kgs.
**Mapleson F**
The Mapleson F or Jackson Rees T-piece, is functionally similar to the Mapleson E. Dr. Jackson added an open ended reservoir bag to the Ayres T-piece to allow for visualisation of respiration and to provide a method of assisting with or delivering ventilation. It still has no valves and therefore little dead space and low resistance. It has a low initial and maintenance cost and is compact to store. Unfortunately, due to the lack of valve, the reservoir bag can easily twist and impede respiration. This also results in very high pressures building up in the chest which can be very dangerous. It is quite a heavy breathing system for very small patients and often has to be secured to the table to prevent any strain on the patient.

![Mapleson F Diagram](image1)

The Mapleson E&F breathing systems function in the same manner. The patient inspires fresh gas and during expiration the waste gas fills the tubing and reservoir bag in the Mapleson F, before being flushed out of the system during the expiratory pause by the continuous flow of fresh gas.

**Mapleson D**
There are two breathing systems which come under the Mapleson D classification. The first is the modified Ayres T-piece with a paediatric valve. This is the most commonly used breathing system for veterinary patients under 10kgs. It has a reservoir bag and an adjustable pressure limiting valve which allows the user to provide IPPV and can attach to scavenging. It has a circuit factor of 2.5-3. It is functionally similar to the other T-pieces but is much safer to use. The APL valve prevents any twisting and therefore occlusion of the reservoir bag. It also means that the anaesthetist can adjust and limit the amount of pressure applied safely with each breath that has to be given manually. This is particularly important in smaller patients who will tolerate much lower peak inspiratory pressures.

![Mapleson D Diagram](image2)
The second breathing system classified as Mapleson D is the Bain. This is a coaxial system where the inner tube carries the fresh gas and the outer tube carries the waste gas. The reservoir bag is on the expiratory limb just as it is on the modified Ayres T-piece. This too has a circuit factor of 2.5-3 and it is suitable for providing manual ventilation. This breathing system should only be used on patients weighing over 10kgs. Due to its size, there is too much resistance for animals any smaller than this.

The advantages of using a Mapleson D breathing system are that it has minimal dead space and therefore little resistance. One of its key attractions is its suitability for long term IPPV. The coaxial Bain benefits from its structure as the inspired gases are warmed by the expired waste gas; however, it is not humidified. It is also its coaxial form which created a disadvantage. The inner tube must be regularly checked for damage and leaks as these can be more difficult to detect normally and it unfortunately requires a high fresh gas flow rate making it the least economical choice.

Fresh gas travels along the inspiratory limb and enters the patient during inspiration. When the patient exhales, the continuous high flow of fresh gas, forces the waste gases to travel along the expiratory limb and out of scavenging. This results in wastage of fresh gas which mixes with the expired gas.

**Rebreathing Systems**

The circle is probably the most commonly used rebreathing system used in veterinary practice today. It is comprised of two unidirectional valves, carbon dioxide absorbent, an APL valve, a reservoir bag and breathing tubes. The arrangement of this system with unidirectional valves ensures the gas can only travel in one direction and therefore must travel through the carbon dioxide absorbent. This means that the inspired gas will be a small amount of fresh gas plus exhaled waste gases minus carbon dioxide.
There are many advantages to using a rebreathing system.

- Firstly it allows for rebreathing by absorbing the CO$_2$ from the exhaled gas leaving oxygen and volatile agent available to be recycled in the next breath.
- It conserves heat & moisture. The gas has already been warmed by the body so when it re-enters the patient it is already humidified meaning very little energy is lost. Human medicine shows us that the average 70kg patient loses 10watts of energy an hour humidifying air when on a non-rebreathing system. This information demonstrates to us that veterinary patients use a lot of their heat energy trying to humidify gas because we provide them with a constant flow of cold fresh gas – this can be prevented with a rebreathing system.
- If the unidirectional valves are functioning correctly then there is little resistance and limited apparatus dead space.
- A rebreathing system is very economical because the gas is recycled, very low flows of oxygen can be used. The fresh gas flow can be as little as 10mls/kg if the carbon dioxide absorbent is fresh and not exhausted.
- There is far less pollution because the gas is recycled so there is less waste gas going out to scavenging and into the environment.
- Rebreathing systems are suitable for both spontaneous and intermittent positive pressure ventilation.

Unfortunately, there are disadvantages to the rebreathing systems as well.

- They have a higher resistance than non-rebreathing systems which is a problem for smaller patients. This is why they are recommended for animals over 10kgs. However, most modern rebreathing systems are made entirely of plastic and paediatric tubing is available for them. This has helped reduce the resistance meaning they can be used on a much wider weight range.
- This does not, however, reduce the amount of apparatus dead space. All patients will still have to breathe against the canister containing the carbon dioxide absorbent.
- If the carbon dioxide absorbent is not packed into the canister properly, channelling of gas can occur. This is when the expired gas enters the canister but because it has
not been filled correctly the gas can leave the canister again without having passed through the carbon dioxide absorbent. This consequently results in the patient rebreathing carbon dioxide and the fresh gas flow rate will need to be increased to prevent this during the anaesthetic making the whole system much less efficient.

- Rebreathing systems are not ideal for use with nitrous oxide as it accumulates in the canister and is also rebreathed. If equipment is available to monitor the amount of end-tidal carbon dioxide, oxygen, volatile agent and nitrous oxide then it can be safely used within a rebreathing system, however, if this is not the case, a rate of 50:50 should be used to avoid the chance of hypoxia or the use of it in a rebreathing system should be avoided altogether.

- Another disadvantage to using rebreathing system is that the concentration of anaesthetic is slow to change. This is partly due to the low flow rates which are used.

- Without specialist equipment it is difficult to know inspired anaesthetic concentration at any point and how quickly it is changing when adjustments are made during the anaesthetic.

The circle functions in the following way:

- During inspiration the expiratory valve closes allowing gas to flow from the reservoir bag & fresh gas inlet to the patient via inspiratory limb.
- During expiration, the inspiratory valve closes. This allows gas to flow to reservoir bag via expiratory limb. Any excess gas escapes via APL valve to scavenging and the \( \text{CO}_2 \) is absorbed in canister.

- The Humphrey ADE is a breathing system which can be used as a rebreathing system or a non-rebreathing system.
- The user can switch between using it as Mapleson A & Mapleson D when it is being used as a non-rebreathing system.
- It can be used with any patients from 2kgs upwards and the user can attach a \( \text{CO}_2 \) absorbent canister for patients over 10kgs.
- It consists of:
  - a lever to allow it to switch between functions
    - Up for Mapleson A
    - Down for Mapleson D
  - a detachable \( \text{CO}_2 \) absorbent canister
  - APL valve, reservoir bag, breathing tubes.
The Humphrey is expensive to buy, maintain and replace any parts however it does have lots of advantages. It is more economical than a lack or t-piece as lower FGF rates required. It has small tubing which reduces the resistance and it is suitable for IPPV in all forms.

**Unidirectional Valves**
- Unidirectional valves are important parts of rebreathing system. The pressure generated by patients breathing causes the disc to rise and gas can only flow in one direction.
- Modern valves are made of plastic which reduces the resistance and chances of the valves sticking.
- Faulty valves create resistance, reduce efficiency of gas circulation and result in rebreathing.

**In Circuit Vaporisers**
- Some rebreathing systems have in circuit vaporisers. They have little resistance and are positioned on the inspiratory limb of the breathing system. The volatile agent is vaporised by gases in the breathing system not by fresh gas entering the system.