**Introduction**

These animations from the charity International Primary Care Respiratory Group (IPCRG) have been designed for healthcare professionals to help patients improve their “breathing literacy”. It is not always easy to understand drawings, so the moving images enable you to see all round the body. We have deliberately used both medical terminology and lay vocabulary. Where images are labelled we have chosen to use medical terms. The voiceover uses both.

The animations can be used in sections. They cover how we breathe, why we get breathless, and why interventions such as breathing positioning, breathing techniques, inhalers and pulmonary rehabilitation work. Our aim is to offer a visual explanation that will aid understanding and potentially improve patients’ capacity to self-manage.

We start with breathing, ventilation, the bronchial tree and respiration. We then look at the causes of breathlessness including obstruction, respiratory muscle weakness, restriction, deconditioning, anxiety and breathing pattern disorder. We then look at what we breathe, and explain good particles and bad particles.

**Breathing: How we breathe**

**Definitions**

People know breathing is essential to life, but why?   Let’s start with some important definitions:

**Breathing** is the work that our muscles do to move air in and out of our lungs.

**Ventilation** is  bringing a gas, oxygen (O2), into our body and getting rid of another gas, carbon dioxide (CO2) from our bodies – (just like we “ventilate” our houses to get in fresh air and get rid of fumes, smoke or COVID.)

**Respiration** means supplying oxygen (O2) to our body’s cells and tissues.

In our bodies, ventilation requires a pump – the ventilatory pump - which requires force to produce the pump action. This is provided by our respiratory muscles when we breathe.

**Ventilation**

Our “ventilatory pump” brings air in and out of our body using three main respiratory muscles: the diaphragm, intercostal and scalene muscles. When they contract, three things happen at the same time. The diaphragm, a large dome of muscle, flattens and pulls down. This increases the height in our thorax or chest. It also pushes our abdomen/belly out (which you can feel if you have a tight waistband!) and moves the lower ribs out a little. The muscles between our ribs, the intercostal muscles, pull the ribcage up and out increasing the width of our chest, and finally the scalene muscles pull the sternum or breast bone up and forward, increasing the depth of our chest. These three movements increase the volume of our chest.

Our two lungs are stretchy and attached to the inside of our ribs, diaphragm and mediastInum by the pleural membranes. These moist pleural membranes are fixed to the inside of our ribcage and surround/cover the surface of each lung and slide against each other. As our diaphragm moves down and our ribs move up and out, the pleura move with them and our lungs are pulled open and expand. Therefore as our chest volume increases, our lung volume increases. Air is sucked in. This is inspiration or inhalation.

As the lungs expand, the air tubes, or airways, inside them, are also pulled open, increasing their diameter.

Expiration or exhalation is the phase of ventilation when air leaves our lungs. Our respiratory muscles relax and our lungs and the air tubes or airways, having been pulled and stretched open, recoil back to their original shape because healthy lung tissue is stretchy or “elastic” - it returns to its resting shape naturally, like an elastic band. Our chest’s height, width and depth decrease, reducing the space and increasing the pressure on, and in, our lungs. Our airways narrow, and the very smallest close, and the “stale” carbon dioxide-rich air leaves our body. Our lungs are never completely empty, otherwise they might  stick together. A “residual volume” is left.

This is known as “quiet breathing”. When we’re relaxed, adults breathe in and out approximately 8-18 times per minute and each breath contains about 500ml of air. This is also known as tidal breathing. Sometimes the tidal volume needs to increase, for example if we exercise.  In pregnancy the tidal volume increases by up to 50% because growing a baby needs more oxygen breathed in  and more carbon dioxide is made that needs to be breathed out. Therefore more of our lungs are used in this extra work.

This mechanical act of the air being drawn in and out of the lungs is ventilation.

Notice how high up the lungs reach in our body and where the diaphragm is. In quiet breathing the diaphragm is responsible for 75% of the breathing effort. Notice that the ribcage goes right round the body: it reaches further down the back than at the front, matching the lungs which do the same; we need to pay attention to the back and front - it is a 3d structure.

**The bronchial tree**

Now we understand ventilation - the mechanics of how air is drawn into our body, we need to understand where the air goes once it enters.

We inhale, breathe in, through our nose or mouth. If we breathe through our nose, there are super-fine hairs and a thin layer of mucus that filter and warm the air and trap dirt, so the air can flow better and bring fewer irritants into our lungs. The air continues down the upper respiratory tract (above the Adams Apple), through the pharynx (throat) and larynx (voicebox). Then it enters the lower respiratory tract (below the Adam’s Apple).

Imagine an upside down oak tree - the bronchial tree - where each bronchus or branch is a tube that the air travels through. Firstly, down the trachea (windpipe), then it divides into two large main bronchi (left bronchus and right bronchus), which lead into each of the two lungs. These branches or bronchi divide and divide and divide, about 23 times, into the narrowest branches called bronchioles before they reach approximately 480 million alveoli – the microscopic air sacs in our lungs. Our lungs also contain mucus to trap harmful bacteria and viruses that cause disease. The bronchi are lined with cilia, microscopically small hairs that keep the thin layer of mucus flowing towards the larynx; this traps inhaled particles, such as we might find in smoke, sweeping them up and out of the body.

It’s important to visualise this journey through what we call the airways – from nose to alveoli, to know the names of each part and for the healthcare professional to be able to pinpoint where a problem might occur and therefore what treatment might be needed.

**Respiration**

How does breathing enable our body to get the energy it needs to survive?

Most of the time we are unaware of breathing, it is a subconscious action. Our brainstem, our signalbox, notices when we don’t have enough oxygen and signals to our body that we need to breathe in, just like the signalbox notices when our stomach is empty and signals we are hungry and need to eat.

When we breathe in air we start the process of getting the oxygen it contains to every cell in our body where the mitochondria, the energy factories, in each cell generate energy. Breathing out gets rid of most of the waste carbon dioxide gas.

When the oxygen-rich air gets to our lungs, oxygen passes through the lungs’ membranes into our blood. The blood carries it to all our organs, including our muscles. Carbon dioxide moves in the reverse direction, from the blood into our lungs, so that we can breathe it out.

This whole process is called “respiration”, although the term is often used just to describe breathing in and out. But you may hear the word because services for people who are breathless are often called “respiratory services”.

Every minute of the day, the whole of our blood volume goes through our lungs.

**Breathlessness**

**Normal breathlessness**

What is breathlessness?

Everyone has felt breathless at some point –  for example, when we’ve pushed ourselves to walk or run fast. This is normal. It’s our body’s natural response when it needs more oxygen and energy to do something that requires physical effort.  Getting out of breath when we exert ourselves like this is good.  It keeps our bodies strong and fit.

However, some of us get out of breath every day doing everyday activities. We find it difficult or uncomfortable to breathe, and may feel we can’t control our breathing. This is known as chronic (long-term) breathlessness. It often develops gradually and lasts for weeks, months or years without us really noticing. Sometimes people also cough, bring up phlegm or feel wheezy.

**Obstruction**

So what is happening in our bodies when we get breathless?
Most commonly, the airflow gets slowed down because there’s an obstruction somewhere in our airways between our nose and air sacs. There are many reasons why they may get obstructed and knowing the reason helps explain the diagnosis. These are the main types of obstruction:

1. The most common reason for obstruction is swelling or inflammation inside our airways or tubes. It happens in asthma and bronchitis (the main cause of COPD). The lining and walls of the tubes are damaged from persistent or recurrent irritation from common irritants such as tobacco or cooking smoke, or allergens. This leads to inflammation. Mucus containing dead cells or bacteria (phlegm) can also build up because the cilia can’t sweep it away. Coughing is our body’s attempt to clear this build-up. Or

2. Obstruction due to weaknesses in our air tubes. In emphysema (also part of COPD) at the point where the smallest bronchioles reach the alveoli, the air sac walls break down creating air sacs that are too large. These larger air sacs are too large for good respiration and squeeze the healthy airsacs down.

In bronchiectasis, the air tubes widen too much and the cilia, the little hairs, cannot carry the mucus to our throat very well so the mucus stagnates; bacteria then grow in these warm, moist conditions. Or

3. Obstruction due to small blockages in the air tubes – from a tumour such as lung cancer. Or

4. Obstruction due to muscle tightening forcing the tubes, our airways, to close up. For example in an asthma attack/bronchospasm the muscle around the bronchi or bronchioles tighten (bronchoconstriction). Or

5. Obstruction due to pressure on the airways forcing them to close up for example from tumours not in the bronchus/air tubes called “non-bronchial”.

If our airways close too soon as we breathe out, or exhale, then the stale air gets trapped and our lungs stay inflated. Our next in-breath stacks on top of our last. We will describe this in more detail later in COPD and a severe asthma attack. If you want to try to imagine how that feels, try to breathe in, hold it in, and then try to breathe in again.

**Respiratory muscle weakness**

Meanwhile, as well as obstruction, our respiratory muscles may not work the way they should. Air trapping can also lead to hyperinflation. The respiratory muscles get stuck in the shortened, contracted breathing-in position; which may not be very effective, and so we have to work harder.

This means we may have more rapid, shallow breathing when we try to do anything. So we may have to use extra “accessory” muscles, not used in quiet breathing, to help expand our chest and lungs. These are our neck and shoulder muscles.

For example, we see this in some sports, where people are exerting themselves a lot. We also see this in people where the air doesn’t flow well due to lung damage.

However, if we need to move or lift up our arms, our neck and shoulder muscles aren’t available for breathing, so our diaphragm has to take most of the load.

Airways obstruction can increase the work of breathing as much as 8 times our normal! We may feel a sense of excessive work or effort to breathe, like breathing is just a slog.

So, we can see that both the airways and the muscles may be working incorrectly in obstructive lung disease. This is why respiratory physiotherapy can help. It helps improve the mechanics of breathing, by careful advice on body position and breathing techniques such as breathing control, relaxed deep breathing or pursed lip breathing. These can empty our lungs of as much of the extra air as possible and return our muscles to a better length and our lung tissue to a better state to reinflate and get new air in. This helps reduce the effort of breathing.

In addition, weak muscles use more oxygen than strong muscles to do the same work. Therefore, very importantly, rehabilitation and exercise improve the way the muscles work, so we use oxygen more effectively.

**Restriction**

Alternatively, breathlessness may be caused not by obstruction, but by restriction to the expansion of our lungs. Our lungs may be restricted either because they shrink and can’t inflate as much as usual, or are squeezed because our chest wall can’t move. The reasons could be:

Our lungs get stiff and can’t expand for example in interstitial lung diseases, or they recoil too much and shrink. Or

The air sacs collapse, or join up or are scarred, due to an infection such as pneumonia, autoimmune conditions. Or

The chest wall is stiff eg in severe scoliosis. Or

Weak or paralysed muscles can’t move the chest wall for example with polio or motor neurone disease.

People with restricted lung disease need help to increase lung inflation for example by body positioning to take the load off the diaphragm, to help it flatten/contract.

**Deconditioning**

We’ve now considered obstruction of our airways, and restriction of our chest wall as possible reasons for our breathlessness. But it may be due to general muscle weakness, body deconditioning.

When we feel tired, we are often less active, and so we sit down more. Our muscles become weaker. Therefore we feel tired and so are less active. The only way to reverse this decline is to become more active.

As we explained earlier talking about respiration, the mitochondria, our energy factories, in our muscle cells generate energy. They need oxygen. If we build more muscle by training our biggest muscles – our leg muscles – we will make more mitochondria and they will use all the oxygen we’ve breathed in and use it more efficiently to make us feel more energised and stronger. Every muscle contraction uses oxygen. Therefore if it is used more efficiently, then we have more for our respiratory muscles so our breathing takes less effort.

Deconditioning is also a common problem for people with COPD and is one of the important reasons pulmonary rehabilitation programmes work. They help us to gain muscle strength and to breathe more efficiently, without using up so much energy. This reduces our feelings of breathlessness.

**Anxiety, thinking**

Breathlessness could also be due to stress or anxiety because it is often not only our breathing and functioning involved, but also our thinking.

When we are scared, our body reacts to get us ready to “fight or run away” and develops a faster breathing pattern, as it tries to get more oxygen to our muscles. We may get hot.

However, we don’t actually fight or run away, and our body’s cells don’t need that increased oxygen, so it’s important to teach our body to relax again. We can retrain our breathing pattern either while we rest or during activity.

This sensation can also happen if we have asthma or COPD. This can be frightening, make us anxious, or panicky; we may even have thoughts about dying. This thinking can make us tense our respiratory muscles and make our breathing worse, which affects our thoughts.

This is when breathing exercises can help - to slow down our breathing, decrease the amount of oxygen our body needs, and use less effort to breathe again.

A tip for someone with emphysema who is breathless and anxious is to focus on a slow long breath out first otherwise air trapping will be made worse.

Sometimes we get suddenly and unexpectedly breathless (known as “acute breathlessness” and then it is important to get assessed by a healthcare professional immediately.

**Breathing pattern disorder**

Finally, breathlessness could be due to breathing pattern disorder (previously called hyperventilation or overbreathing), which nearly always had an emotional cause at the beginning but is now our usual breathing pattern. We might have “air hunger” where we think we have to take in more air than we need; where our breaths feel “too small”. 1 in every 4 people with asthma has this problem. Breathing retraining can help, guided by respiratory physiotherapists.

**What we breathe in: bad and good particles**

We can breathe in not only oxygen but potentially harmful particles such as smoke and other pollution, and also helpful particles, such as the medicine in inhalers. We can see how particles of different sizes lodge in different places in our bronchial tree depending on the size of the particle and the speed with which we inhale it.

We are normally able to cough or sneeze out the largest particles.

However, we don’t cough or sneeze out smaller particles. Those with a diameter of 10 microns or less, (≤ PM10) can penetrate and lodge deep inside our lungs. The even more health-damaging particles are those with a diameter of 2.5 microns or less, (≤ PM2.5). These particles are so small that 60 of them make up the width of a human hair.

PM2.5 can pass through our lungs and enter our blood, just like oxygen. They can increase our risk of heart and respiratory diseases, as well as lung cancer.

On the other hand, we want the medicine we inhale to stay in our lungs so this is normally manufactured to be fine (5 microns) or ultrafine. This is why it is important that we follow instructions about how to use our inhaler: slow and deep if using a pressurised Metered Dose Inhaler (pMDI) and suck fast, deep and hard if it’s a Dry Powder Inhaler (DPI). The aim is to get the medicine into our lungs, not stuck in our mouth or throat. If we use a pMDI, use it with a spacer to ensure we breathe the medicine into our lungs and it doesn’t get deposited and wasted in our mouth and throat.

**Steps shown in inhaler clip**

1. I’m preparing the inhaler device and spacer
2. I prepare the dose
3. I breathe out away from the device
4. I tilt my chin slightly; I form a nice seal
5. I breathe in - slow and steady - and press down on the pMDI canister soon after breathing in
6. I hold my breath for 10 seconds
7. I will then wait 60 seconds before taking a second dose

**Summary**

To summarise, the more we understand about respiration and ventilation including the mechanics of breathing, the bronchial tree and lungs, obstruction and restriction, the more we can understand the symptom of breathlessness and how to diagnose and treat it. This should increase confidence of patients and clinicians to communicate effectively, select and use the right tests and treatments. Ultimately, our aim is to help patients breathe better, feel good and do more.