Royal College of Physicians

BREATH AND BREATHING

An in-depth look at the processes involved in breathing, and the difficulties faced by sufferers of breathlessness

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Chest physicians and RCP fellows Nigel Cooke and Noel Snell take an in-depth look at the processes involved in breathing, and the difficulties faced by sufferers of breathlessness.

A booklet in response to the 'Catch Your Breath' exhibition at the Royal College of Physicians (2 April to 20 September 2019), which is based on the research of the Life of Breath project.

Nigel Cooke

While I was a student in the early 1970s I always intended to become a physician and deal directly with patients. I chose respiratory medicine as it offered a wide range of diseases from asthma to lung cancer.

I worked as a consultant physician for 26 years and soon realised that one of my major roles was looking after respiratory patients with chronic disease. My area of special interest was tuberculosis (TB), especially with its links to patients with AIDS. By the end of my career this disease was controlled and patients had a good quality of life and life expectancy.

I have always been interested in the social history of medicine, especially in relation to TB, so this leaflet is an extension of that interest.

Noel Snell

I qualified at St Bartholomew's Hospital, London, and trained in respiratory and general medicine before spending several years as a clinician scientist in the Medical Research Council Tuberculosis and Chest Diseases Unit. I then worked mainly in clinical research, before being appointed director of research at the British Lung Foundation (BLF), from 2013–15.

My particular research interests are in the clinical pharmacology of the respiratory system, respiratory infection, inhaled drug delivery, respiratory adverse drug reactions, botanical origins of modern medicines, and the history of respiratory medicine and tuberculosis. I am currently an honorary senior lecturer at the National Heart and Lung Institute (Imperial College) and a vice president of the British Lung Foundation.

Acknowledgements

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Cover image: The 'Burroughs' ammonia inhaler from *Medical Formulae*, 1881. Wellcome Collection

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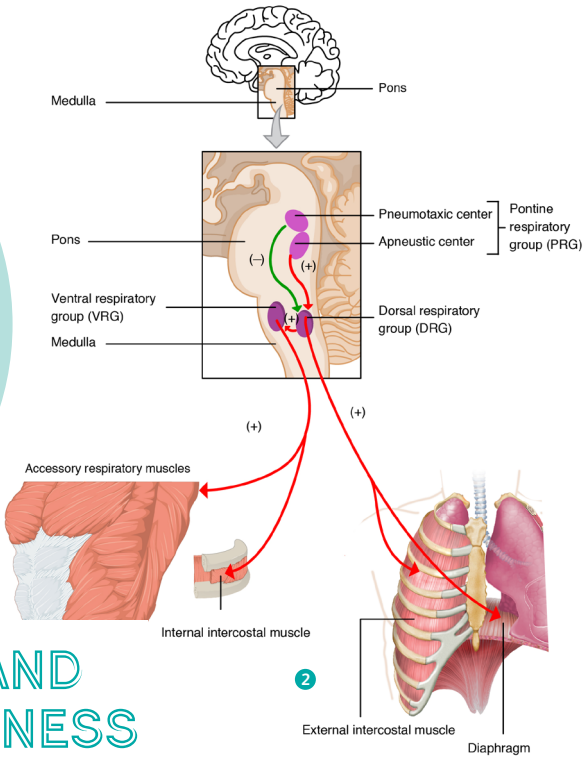

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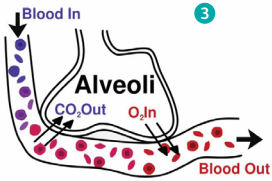
BREATHiNG AND BREATHLESSNESS

Breathing is essential to our lives, from the first inspiration of the newborn baby which expands its lungs, to our dying expiratory breath. We normally breathe regularly without conscious thought, around 15 breaths per minute at rest. Each breath typically moves about half a litre of air in and out of the lungs. Breathing is controlled by the respiratory centre in the brainstem. It responds to the level of the waste gas carbon dioxide (CO_2) in the blood and adjusts the rate and depth of ventilation to keep the concentration within normal limits.

The surface of the lung where this gas exchange takes place is extremely thin, and estimated to cover about 150 square metres in area – nearly the size of a tennis court. If the gas-exchanging surface of the lungs is damaged, or the respiratory muscles are weak, levels of CO_2 in the blood can rise (and oxygen levels fall) and cause breathlessness. This can be the result of lung disorders such as chronic obstructive pulmonary disorder (COPD), lung cancer or asthma. There is a very rare neurological condition, Ondine's curse, in which the sufferer fails to breathe adequately unless actually concentrating on doing so; when asleep they require assisted ventilation.



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Breathlessness can also be caused by conditions unrelated to the lungs. It can be a symptom of anaemia, where there is insufficient haemoglobin (the oxygen-carrying protein) in the blood to transport the required amount

1 First breath. Creative Commons

2 Respiratory centres of the brain, from Anatomy & Physiology, Connexions Website: http://cnx.org/content/col11496/1.6/, Jun 19, 2013.

3 Gas exchange on the surface of the lungs. Creative Commons

4

of oxygen around the body. Heart disease can mean the heart is not strong enough to pump enough deoxygenated blood through the lungs. People who have severe diabetes with very high blood sugar levels may develop ketoacidosis because of metabolism of body fats, and experience a characteristic 'air hunger'. The condition may be diagnosed by noticing the odour of ketones on the patient's breath.

There are other causes of breathlessness, for example strenuous exercise and high altitudes. Anxiety or panic attacks can cause hyperventilation, where the level of CO_2 in the blood falls too low because of the increased rate of breathing. This can lead to tingling in the skin and muscle spasms. The traditional treatment of breathing in and out of a paper bag may actually be effective in these instances – the exhaled CO_2 is recycled, bringing levels of the gas in the blood back to normal.

4 Mount Everest as seen from an aircraft, 2012. Creative Commons

5 British Lung Foundation logo

EXPERIENCING BREATHLESSNESS

Breathlessness can be an unpleasant and often frightening experience. The feelings of some sufferers are documented on the British Lung Foundation's website, and can be found at www.blf.org.uk/breathlessness:

'My chest tightens. I feel I am breathing against a wall and the wheezing and coughing start'.

'… as long as it works, we all take breathing for granted. I am now aware of every breath I take and of its quality'.

Acute breathlessness can occur because of obstructed airways during an asthma attack, infections such as pneumonia, and less common conditions such as a collapsed lung (pneumothorax) or a clot in the blood vessels in the lung (pulmonary embolus).

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Chronic breathlessness, on the other hand, is seen in lung conditions such as COPD (usually caused by smoking, or breathing in other pollutants); and lung fibrosis, scarring of the lung tissue which may develop for no obvious reason, or in association with conditions such as rheumatoid arthritis, or from occupational exposure to substances such as asbestos or silica.

In both acute and chronic breathlessness, the lungs work harder to function, and this can be exhausting. One way patients find to cope with this is by adopting specific postures to help them breathe. In 1698, in his book *A treatise of the asthma*, the physician Sir John Floyer (1649–1734) reported a patient as saying:

'I slept in a chair leaning on a table ... for many times my wheezing will leave me in sleeping thus: but if I lean back but a little in a chair to sleep, or in my bed raised with pillows, I shall wheeze the more'.

These postures are still used today to help relieve the symptoms of breathlessness.

The 19th-century physician Henry Hyde Salter (1823–71) quoted an asthmatic patient describing a bad attack:

'With bent back, high shoulders, and elbows fixed on the chair-arms, I had been labouring for breath all the afternoon'.

6 X-ray showing bacterial pneumonia. Wellcome Collection

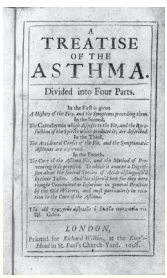
7 CT scan showing a collapsed lung (pneumothorax) on the right-hand side of image. Creative Commons

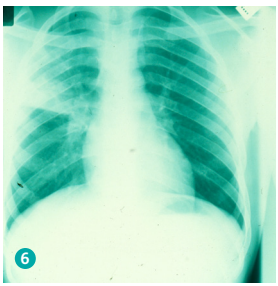
8 Diagram showing how COPD affects the lungs. Creative Commons

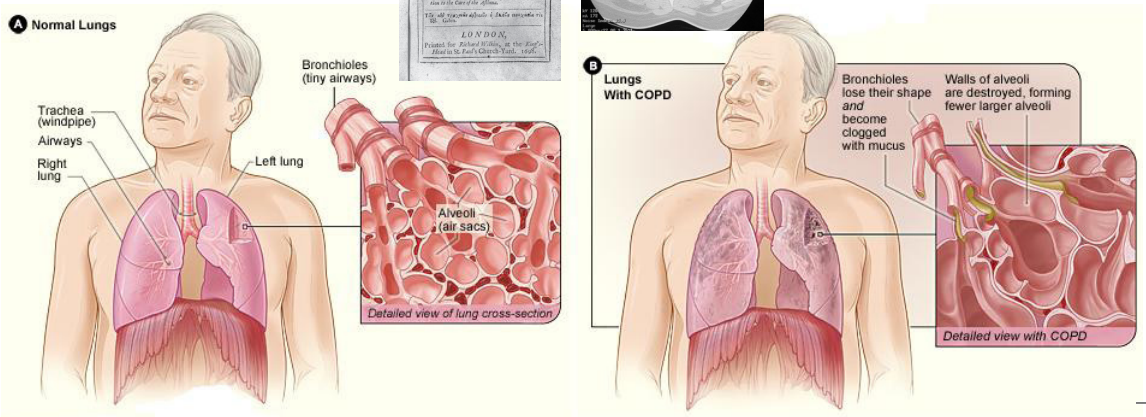
9 Sir John Floyer, *A treatise of the asthma* (1698). Creative Commons

10 How posture can help asthma sufferers. Firstaidforlife.org

11 Parker's tonic, showing a sufferer from breathlessness adopting the position described by Henry Hyde Salter. Creative Commons







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ASSESSING BREATHING, BREATH AND BREATHLESSNESS

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Spirometers

The respiratory rate, ie breaths per minute, can be counted. The volume of air breathed in and out is easy to measure using a spirometer. Various attempts to measure expiratory volumes were made over the centuries but the first accurate device is usually ascribed to the Englishman John Hutchison in the mid-19th century. The modern spirometer is still an important diagnostic instrument.

The amount of air breathed in and out while the patient is resting is called the tidal volume. The volume exhaled after a deep breath in is the vital capacity. There is always some air left in the lungs after a complete expiration – this is the residual volume.

A good measure of the degree of obstruction in the airways is the maximum volume of air that can be exhaled in a set time, usually 1 second. This is often expressed as a percentage of the vital capacity measured during the same exhalation. This ratio is normally greater than 70%.

In people with severe COPD, or during a bad asthma attack, it may be as low as 30-40%. Patients with lung fibrosis may have little obstruction but because their lungs are stiff they will have reduced vital capacity.

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12 Lowne portable spirometer, London, England, 1880–90. Science Museum, London

13 Hutchinson's spirometer, 1846. Wellcome Collection

14 Pneumotrac spirometer. Vitalograph.co.uk

15 Monaural stethoscope of the Laennec type, purchased by WW Fisher in 1825. Wellcome Collection

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Stethoscopes

Stethoscopes can be used to listen to the sounds of breathing in the chest. The sound of diminished breathing in a localised area of the lung can indicate a collapsed lung or fluid around the lung (a pleural effusion). Wheezing sounds are caused by prolonged expiration through narrowed airways, and suggest asthma or COPD.

The stethoscope was invented by the French physician, René Laennec (1781–1826), in 1816. A stethoscope owned by Laennec is on display in the Catch Your Breath exhibition.

Gas analysers

The concentrations of carbon dioxide and oxygen in the blood can be measured using a gas analyser and a blood sample from an artery (which carries oxygenated blood away from the heart). The approximate level of oxygen in the blood can also be monitored using a pulse oximeter, a non-invasive instrument which measures light transmission through a fingertip or earlobe with a photometer.

Recently there has been much interest in assaying other gases and volatile organic compounds in exhaled breath, in the hope that novel biomarkers of disease might be identified. For example, the concentration of nitric oxide is elevated in some inflammatory disorders of the lung such as asthma, and a fall in the level reflects improved asthma control. Carbon monoxide (CO) is produced by lighted cigarettes, and a raised level of exhaled CO reflects recent smoking.

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16 Pulse oximeter. Creative Commons

TREATING BREATHLESSNESS

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Specific causes of breathlessness such as anaemia and pneumothorax (collapsed lung) can be treated and cured. However, many conditions causing breathlessness are chronic, and treatment can only lead to the improvement of symptoms.

Measures can be taken to help reduce breathlessness, for example weight loss and stopping smoking. Even people with quite severe lung disease can benefit from a fitness programme, and from learning efficient breathing techniques. Some patients find yoga helpful. The British Lung Foundation has sponsored nationwide 'Singing for Breathing' projects, aimed at improving lung performance, and providing a social support network for sufferers from breathlessness.

Patients with airway obstruction, such as asthma and COPD, usually benefit from a bronchodilator medication, administered by an inhaler. Those who produce large volumes of sticky sputum, such as people with chronic bronchitis, bronchiectasis, and cystic fibrosis, find chest physiotherapy helpful. The ancient treatment of steam inhalation – from a 'steam kettle' – can still be beneficial today.

Patients whose oxygen levels are too low, even while resting, are assessed by a lung function technician or physiotherapist for supplemental oxygen therapy, such as the use of an oxygen cylinder. In severe cases assisted ventilation may be required, either just at night or during the day as well.

Sometimes the effort of breathing to maintain oxygen and carbon dioxide levels is so exhausting that drugs such as codeine or morphine may be used to depress the drive to breathe and relieve discomfort, even if their blood gases go outside the normal limits. This is usually in the late stages of the disease. It does not, however, cure the cause of the breathlessness.

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17 Yoga. Creative Commons

18 Bronchitis kettle by Allen and Son, 1840–1900. Science Museum, London

PUBLIC HEALTH AND BREATHING

Smoking

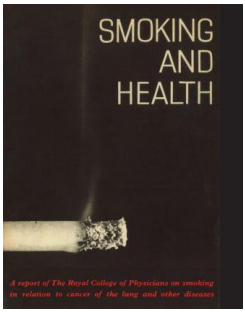
When tobacco smoking was originally introduced from North America in the 16th century, it was considered beneficial for many respiratory diseases. King James I, however, was not convinced:

'A custome lothsome to the eye, hateful to the nose, harmfull to the braine, dangerous to the lungs, and the blacke stinking fume thereof, neerest resembling the horrible stigian smoke of the pit that is bottomelesse.'

***Counterblaste to Tobacco* (1604)**

The monarch was in the minority, and the 'benefits' of smoking were promoted at least until the 1960s. Products such as 'Potter's Asthma Cure', which combined tobacco with a mild bronchodilator, were only taken off the UK market in the 1980s.

A landmark 1950 report by the epidemiologists Sir Richard Doll and Sir Austin Bradford Hill conclusively showed that tobacco smoking was associated with the development of lung cancer. This was followed by the Royal College of Physicians' ground-breaking report *Smoking and health*, published in 1962, which also linked smoking to a range of other diseases. More recently, the known harmful effects of passive smoking resulted in the introduction of legislation in 2007 which banned smoking in indoor public places, and more recently in cars with children as passengers.



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18 *Smoking and health* (1962). Royal College of Physicians

19 Advertisement for Craven 'A' cigarettes featuring Stanley Matthews. Science Museum, London

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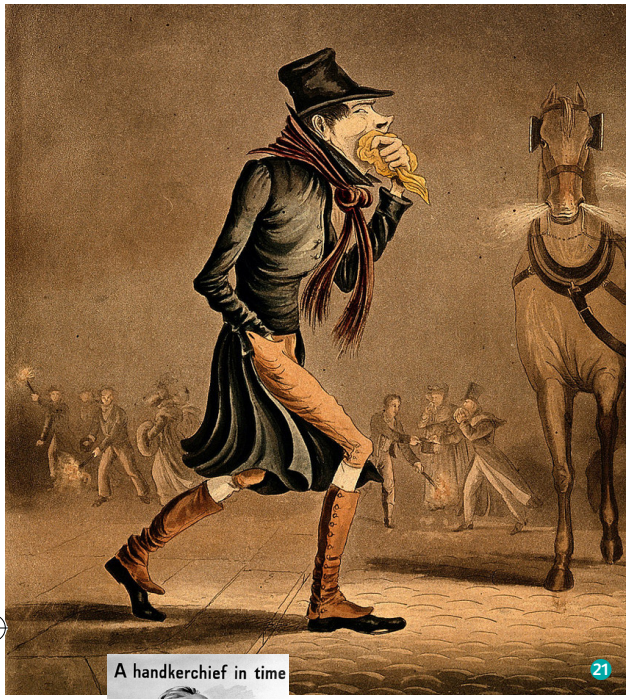

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Other public health concerns

Occupational lung diseases and allergic disorders – caused by inhaling harmful substances such as asbestos, silica, flour and isocyanates – are now widely recognised, and these substances have either been banned or strict protective measures instituted.

Air pollution is now an increasing concern. Following the great London 'smog' of 1952, legislation was introduced to reduce the use of coal in domestic fires. The focus today is on small-particle pollution, particularly from diesel engines.

Lastly, exhalation – in particular coughing and sneezing – can spread infectious diseases such as the common cold, influenza, and TB to healthy subjects who inhale the infected droplets.

TUBERCULOSIS – THE ROMANTIC DISEASE

Tuberculosis (TB) still causes over one million deaths worldwide every year.

In the Victorian era TB was given romantic associations. People with TB displayed symptoms similar to love sickness, including slimness, pale skin and flushing, while many great composers, authors and artists suffered from the illness, for example Frédéric Chopin, the Brontë sisters, and John Keats. The concept of 'Spes phthisica' – that TB could enhance hopefulness and creativity – was widespread. In reality, patients suffered from fever, sweats, a productive cough (often bloodstained), and death or prolonged disability and breathlessness.

23

21 London fog, 1802. Wellcome Collection

22 Coughs and sneezes spread diseases, 20th century. Wellcome Collection

23 TB patient getting fresh air, c1900. Wellcome Collection

24

The infectious nature of TB, and the lack of effective therapy, led to the segregation of patients in sanatoria, where they could benefit from rest, nourishment, and fresh air. When the infectious nature of the sputum produced by people with TB was recognised, spitting was banned in the sanatoria, and portable spittoons were provided for the collection and disposal of sputum.

As there were no effective medications to treat TB, surgery was used to collapse and 'rest' the affected lung, helping cavities heal. This could be done by introducing air into the pleural space via a needle (pneumothorax), or more invasively by opening the chest and packing the space with plastic sponges or Perspex balls. A more extreme option was thoracoplasty, the irreversible removal of ribs on one side of the chest. More often than not, these treatments led to a permanent reduction in the lung's vital capacity, and deformity.

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The discovery and introduction of effective anti-tuberculosis drugs in the late 1940s and early 1950s changed everything. Research conducted by the Medical Research Council's TB and Chest Diseases Unit in Madras, showed that for patients taking effective drug treatment, such as streptomycin, confinement in a sanatorium made no difference to their outcomes. Neither did confinement reduce the transmission of infection, compared with a control group who took their medicines at home. The sanatorium era was over.

TB is now uncommon in the UK, with about 5,000 new cases per year. It is, however, still prevalent in developing countries and the countries of the old Soviet Union. Despite modern medicines and diagnostic methods, deaths from TB in the UK are not uncommon, often because the diagnosis is not suspected and made too late, or because the patient has an antibiotic-resistant strain of the disease. In addition, treatment has to be given for at least 6 months, and many patients fail to complete the course. TB is more common in alcohol and drug-dependent patients, and homeless people.

24 West Midlands tuberculosis sanatorium, date unknown. Heart of England NHS Foundation Trust

25 Portable spittoon, from author's collection. Noel Snell

MEDICINAL PLANTS USED TO TREAT BREATHING PROBLEMS

Plant-derived medicines have been used for centuries to treat breathlessness and disorders of the respiratory system. Botanicals have also been used successfully for non-respiratory causes of breathlessness, eg digoxin (from foxglove, *Digitalis lanata*) for heart failure.

The following are all plants from the RCP's Medicinal Garden which have been used in the past or have led to effective modern medicines for respiratory conditions.

Tours of the RCP's Medicinal Garden are held on the first Wednesday of the month at 2pm from March to October. Please call 020 3075 1649 to book.

Group tours can be arranged at other times via the social events manager on 020 7034 4901. For other garden enquiries, please contact garden@rcplondon.ac.uk

Anticholinergic bronchodilators

These plants relax the smooth muscle in the bronchial tree by blocking the action of the parasympathetic nervous system, giving effective relief from the breathlessness of asthma and COPD.

***Atropa belladonna* (deadly nightshade)**
The main active ingredient in *Atropa belladonna* is atropine, but there are also smaller quantities of hyoscine (scopolamine) and hyoscyamine. These have all been used for the treatment of chest tightness, usually by inhalation. Atropine is still in clinical use, as are modern derivatives such as ipratropium bromide. All three are toxic if overdosed, causing a rapid heart rate, hallucinations, and potentially fatal cardiac arrhythmias.

26 Atropa belladonna. © Dr H F Oakeley

***Datura stramonium* (thorn apple)**
This plant contains hyoscine. It was the major constituent of 'asthma cigarettes', such as Potter's asthma cure, available in the UK until the early 1980s.

Sympathomimetic bronchodilators

These plants act by stimulating the sympathetic nervous system, leading to relaxation of the airways, either directly (ephedrine), or by inhibiting the breakdown of endogenous stimulants (xanthines).

Ephedra sinica
Ephedra was the major active ingredient of a traditional Chinese medicine for asthma, *Ma Huang*. The active principle, ephedrine, was identified in 1887, and then introduced to the west in the early 20th century. Pseudoephedrine is a better-tolerated derivative, and is available as a nasal and bronchial decongestant.

***Camellia sinensis* (tea plant) and *Coffea arabica* (coffee plant)**
Tea, coffee, and cocoa contain variable quantities of the xanthines theophylline, caffeine, and theobromine. These agents inhibit the enzyme phosphodiesterase, leading to a weak bronchodilator effect. Theophylline also has mild anti-inflammatory properties. In 1860 the English physician Dr Henry Hyde Salter (1823–71) advocated the use of strong coffee for the treatment of asthma – today, doctors would prescribe a salbutamol inhaler instead. Recently, a specific inhibitor of one of the subtypes of phosphodiesterase (PDE4) has been developed for the treatment of COPD and asthma.

27 *Datura stramonium*. © Dr H F Oakeley
28 *Ephedra sinica*. © Dr H F Oakeley
29 *Camellia sinensis*. © Dr H F Oakeley

Anti-allergics

***Ammi visnaga* (toothpick plant)**
Extracts from this Mediterranean plant have traditionally been used to treat renal colic, as it relaxes the muscle in the ureter. In the 1960s an English researcher, Roger Altounyan (1922–87), wondered if it might also relax the bronchial muscle and discovered the derivative sodium cromoglycate, which is effective against asthma when inhaled. This was not a bronchodilator as he expected, but an agent that blocked the allergic response leading to an asthmatic attack when given prophylactically.

Breathing depressants

Occasionally patients with severe lung disease become so breathless that they become distressed, and exhausted by the effort of breathing. It may be justifiable to suppress the rate of breathing to make the patient more comfortable. Alcohol is quite effective in this regard, although opiates have a greater effect.

***Papaver somniferum* (opium poppy)**
Opium from the sap of poppy seed capsules has been used for pain relief for over 5,000 years. The active ingredients are morphine and codeine. Both are also effective depressants of respiration.

Morphine relaxes the pulmonary blood vessels, and can help breathlessness caused by pulmonary oedema (waterlogging of the lungs due to heart failure or acute lung injury). Codeine is still used as a symptomatic cough suppressant.

'Therapeutic smoking'

Nicotiana tabacum* and *Nicotiana rustica
From the time of its introduction to Europe

30 *Ammi visnaga*. © Dr H F Oakeley
31 *Papaver somniferum*. © Dr H F Oakeley
32 *Nicotiana tabacum*. © Dr H F Oakeley
33 *Lobelia tupa*. © Dr H F Oakeley
34 *Tulbaghia violacea*. © Dr H F Oakeley
35 *Pelargonium sidoides*. © Dr H F Oakeley

from North America in the 16th century, up until the middle of the 20th century, many doctors and patients believed that tobacco was beneficial to their lungs. Smoking tobacco and cannabis was thought to relieve symptoms of asthma and bronchitis, possibly because the irritant effect helps patients clear their phlegm. The addictive substance in tobacco is nicotine.

Lobelia tupa

Lobelia leaves were dried and smoked by Native Americans as a mild narcotic. Lobelia contains the alkaloid lobeline, which is a mild respiratory stimulant and bronchodilator. It has structural similarities to nicotine and has been used as a smoking cessation aid.

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Tuberculosis

A variety of plant remedies have been used ineffectively to treat TB over the centuries, including balsam, myrrh, and eucalyptus. Semi-synthetic derivatives from the Malabar nut tree (*Justicia adhatoda*), bromhexine and ambroxol, are mildly effective mucolytic agents (ie they make the mucus less thick and sticky, and easier to cough up), but also show some activity against the tubercle bacillus.

***Tulbaghia violacea* (African wild garlic)**

This attractive plant has traditionally been used in southern Africa for the treatment of colds, asthma, and pulmonary tuberculosis.

***Pelargonium sidoides* (Umckaloabo)**

Another southern African plant, this is a constituent of a patent medicine marketed in the UK in the first half of the 20th century. It is still available as a mildly effective cough and cold remedy. Recent testing has shown some antibacterial effects including modest activity against the tuberculosis bacillus.

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FURTHER READING

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