RESPIRATORY STRUCTURES AND GAS EXCHANGE

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Summary

The lungs move air in and out like bellows. Fresh, oxygen-rich air mixes with intrapulmonary air. Oxygen is carried with the circulation and carbon dioxide is excreted with the exhaled air. Various mechanisms maintain the purposeful distribution of ventilation and circulation. Very much of the complicated physiology and pathophysiology is already known, and it has recently become possible to observe changes at the molecular level.

Lung health can readily be well maintained unless it is lost through pollution, especially smoking.

1. Introduction

Life in the Earth's atmosphere is bound with respiration. The oxidative processes within cells are called *internal respiration*. The various processes helping the cells to maintain appropriate inflow of oxygen and outflow of carbon dioxide are called *external respiration*. Different organisms have developed a multitude of ways to deal with the atmospheric environment and to regulate their internal milieu. Breathing is usually thought of as the bellows function of inhaling and exhaling gases, but in fact there are many processes working in smooth succession and simultaneously. These steps will be described in this chapter, with the main focus on the human (and to some extent other mammal) respiratory system.

Understanding of human respiratory physiology has made it now possible to sustain life during space flights and deep sea diving.

The average adult person ventilates about 10 000 liters of air every day. Inspired air is cleaned, moisturized and warmed before entering the lungs. The inhaled substances may cause allergic, inflammatory, constrictive and toxic reactions. Tobacco, industrial and traffic pollutants pose a major threat. More and more evidence on the detrimental effects of even passive smoking has emerged. In spite of the strong evidence of tobacco as the main cause of chronic obstructive lung disease, the pandemic of smoking is spreading. The effects of industrial and traffic pollutants are augmented in smokers and lead to greater disability.

The primary pathology of asthma is an inflammatory reaction or condition in the lungs. The inflammation depends on inhaled allergens, post-infectious changes or exposure to extremely cold air or other irritant factors. Pharmacological studies try to find new molecules to prevent the "inflammatory cascade".

Oxygen delivery is critically dependent on circulation. Maintenance of circulation and matching ventilation and blood circulation in the lung tissue is the prerequisite of oxygen transfer. Pulmonary infection, circulatory shock, trauma and other causes jeopardize the match of ventilation and perfusion. This can lead to the condition often called "acute respiratory distress syndrome", in which various inflammatory reactions derange the pulmonary tissue and obstruct the pulmonary capillaries, impeding blood flow.

Breathing is controlled tightly through a very delicate nervous system. During wakefulness the adaptation of respiration is normally so good that the control is hardly perceived. During sleep, recumbency or drug effect the control is not so perfect, and disturbances in ventilation and maintenance of adequate oxygenation may ensue. One such example is "sleep apnea" which mostly affects older, overweight persons during sleep. The imbalance leads to frequent arousals, which impair sleep and cause daytime tiredness. There are mechanical and other causes for this condition, but a multitude of patients are nowadays treated with night-time nasal ventilation support.

There is still much to be learned about the physiology of respiration while many things have been explained in such detail that we can use them in everyday life and medicine.

The respiratory apparatus consists of the respiratory tract, lungs, chest wall and the respiratory muscles.

The nose, mouth and pharynx conduct the air to the lungs (Figure 1).

The nasal airway provides cleaning, moisturization and thermal balancing of the inspired air. The nasal airway resistance can be changed by congestion and decongestion of the blood vessels in the nasal mucosa. Air is cleaned and filtered by encountering the mucous-coated linings.

The heat exchange is very effective; inspired air is heated to 36 ºC during normal breathing (when ventilation is very fast during exercise in cold weather, much colder air can enter the lungs). The humidification is also very good under normal circumstances: inspired air is humidified to 70-80%, and water is absorbed from the expired air so that the loss is insensible. The water exchange is combined with the function of the mucociliary system. It has been calculated that the respiratory epithelium and the mucous glands produce more than 100 ml of secretions every day. The mucus contains enzymes to degrade microbes and other foreign material. There are also antibodies to encounter different intruders.

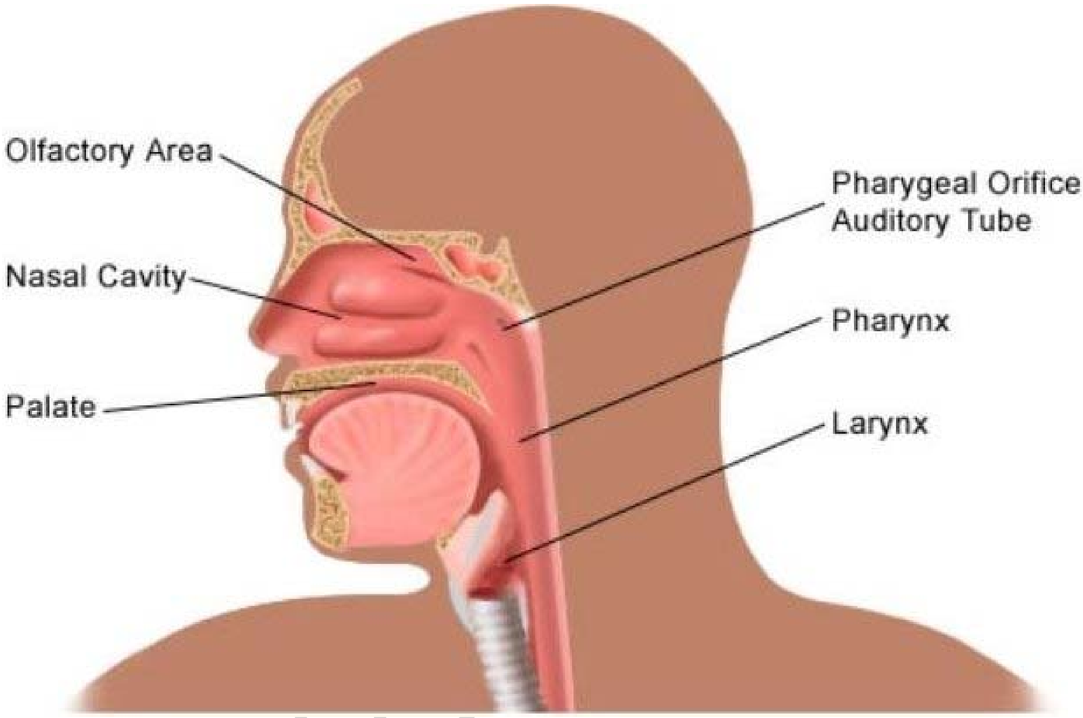

Figure 1. Schematic sagittal drawing of the upper respiratory tract.

The nose is the organ for the very important sense of smell (olfaction). Most of the olfactory neurons are situated on both sides at the ceiling of the nasal cavity and they enter the brain as the olfactory nerve. There are also general sensory neurons leading to the trigeminal nerve.

Under normal conditions, air flows freely through the nose and upper respiratory tract. The passage of air is usually silent, even during sleeping while lying in bed. However, different causes can make the airway narrower. This may lead to mouth breathing, and subsequently to vibration, which is called snoring. For instance, the tongue may fall back, the soft palate may bend down, the throat muscles may become too relaxed, and the nostrils may be blocked by nasal congestion. Obesity aggravates these changes, and the flow of air can be temporarily stopped so that obstructive sleep apnea ensues.

The lungs fill most of the thoracic cavity surrounding the heart and the great vessels and oesophagus from both sides (Figure 2).

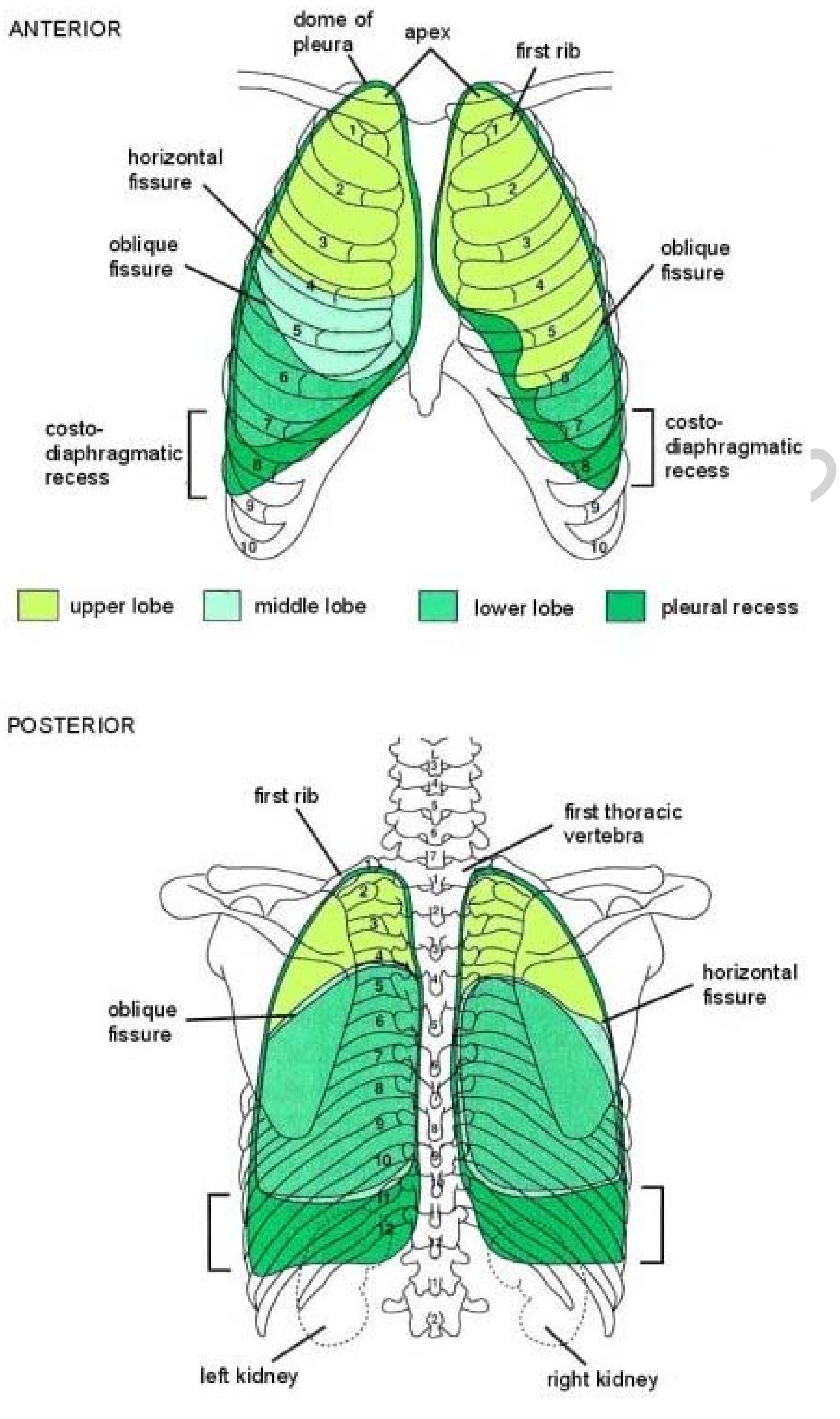

Figure 2. Schematic drawing of the lungs in the thoracic cage. With permission from: Laitinen A and Laitinen A. (1997). Keuhkojen kehitys, anatomia ja histologia [in Finnish]. *Keuhkosairaudet* (ed V. Kinnula, P. Tukiainen, L.A. Laitinen). Jyväskylä, Finland: Duodecim.

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Biographical Sketches

Yrjö Salorinne, MD, PhD, is presently chief physician at the Department of Clinical Physiology and Nuclear Medicine at Helsinki University Hospital and associate professor of clinical physiology in the medical faculty of the University of Helsinki, Finland. His scientific works are mainly on respiratory physiology and lung diseases, and he is a co-author of many textbooks and reviews. He has been active in medical organizations and a co-editor of the Journal of Clinical Physiology.

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