

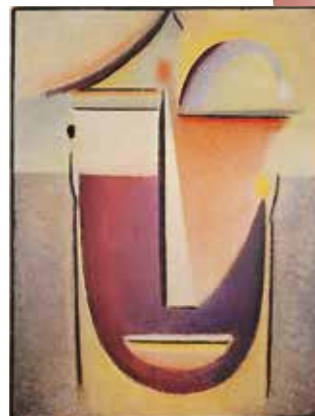


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Physiology

*Organphysiology
from a Phenomenological
Point of View*

Christina van Tellingén MD



BOLK'S COMPANIONS
FOR THE STUDY OF MEDICINE

LOUIS BOLK
I N S T I T U T E

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The Louis Bolk Institute has conducted scientific research to further the development of organic and sustainable agriculture, nutrition, and health care since 1976. Its basic tenet is that nature is the source of knowledge about life. The Institute plays a pioneering role in its field through national and international collaboration by using *experiential knowledge* and by considering data as part of a greater whole. Through its groundbreaking research, the Institute seeks to contribute to a healthy future for people, animals, and the environment. For the Companions, the Institute works together with the Kingfisher Foundation.

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About the Author

Christina van Tellingen MD (1949) has been a general practitioner since 1982. She has educated medical students, physicians, and therapists in the United States, Canada, and Europe. She teaches medical students and physicians at the University of Witten/Herdecke, Germany. She is a member of the Medical Section of the School of Spiritual Science at the Goetheanum, Dornach, Switzerland.

About the Project

The project *Renewal of Medical Education* aims to produce Companions that demonstrate how the insights of current biomedical science can be broadened by using the Goethean phenomenological method. This method innovates current concepts and expands the understanding of biochemical, physiological, psychological, and morphological factors in living organisms and their development in time and space, and in health, illness, and therapy. The project is commissioned by the Kingfisher Foundation, which aspires the development, application, and publication of the Goethean phenomenological research method in the widest

sense, to complement and innovate the accepted scientific view and research method.

BOLK'S COMPANIONS FOR THE STUDY OF MEDICINE complement current medical education, specifically disclosing human qualities in the fundamental biomedical sciences of today.

BOLK'S COMPANIONS FOR THE PRACTICE OF MEDICINE contribute to a scientific phenomenological basis for integrative medicine and integral psychiatry.

1. Introduction

How can we do justice to life itself when studying the life sciences?

In his book, *Lifelines*, Steven Rose states: "The challenge to the opponents of biological determinism is that, while we may have been effective in our critique of its reductionist claims, we have failed to offer a coherent alternative framework within which to interpret living processes." (Rose 1998)

This module offers an alternative framework. In trying to remedy the problem, we have striven for two goals: first, to introduce a new coherent framework in physiology, and second, to show that this framework opens up new possibilities for interpreting physiological processes. We achieve the characterization of a new framework by using a phenomenological approach to physiology. Phenomenology approaches life from the point of view of the whole, such as the whole organism or the whole of an ecological system. This allows the facts of physiology to be placed in a different relation to each other. The new insights that evolve from this approach can be interpreted with the methods of Goethean science, which places the facts in a context, as is described in the foreword. Physiology is typically concerned with *living* organisms. Organisms function as a whole, and physiological processes in organisms are interrelated as a consequence.

Four organ systems will be examined: the lung and respiratory tract, the liver and digestive tract, the kidneys and urinary tract, and the heart and circulation. We will try to find where and how their physiological processes fit into the whole of the organism, and at the same time if they have a *prototypical* place and function in it. We chose these four organ systems because they allow us to see that organs are subject to *different formative principles* in their formation and physiology. These underlying principles are themselves related to forces in nature and appear in a definite order wherever they are at work. All mammals and humans have hearts and lungs; we will demonstrate where in the human organism and in living nature the principles underlying heart and lung have been perfected and play a special role. This will augment our understanding of the function of organs as well

as of the organism as a whole. We will do this by first looking at:

- the **physiological morphology** of organs: their gross anatomical characteristics (shape), their inner structure (histology) and the embryological processes that led to these
- an overview of the **blood supply**
- the relevant **physiological facts**
- the way the organ physiology is **regulated** in the organism and itself regulates the organism
- the **function** of the organ for the organism as a whole
- followed by the **conclusions** regarding the physiology of this organ from a phenomenological point of view.

The **last chapter** (Chapter 6) presents a review and puts the four organs in relation to each other. This offers the possibility to interpret the facts in context and gain a larger view of the role of these organs and the formative principles that underlie them.



Fig. 1.1. These four Egyptian canopic jars were found in the graves of pharaohs. They each contained one of four organs of the deceased. The Egyptians often buried the organs separately next to the mummified body (private slide series)

2. The Lung and Respiratory Tract

2.1. Introduction

The respiratory tract allows gaseous substances from the surrounding air (chiefly oxygen - O₂) to enter the aqueous milieu of the organism, and metabolically generated gases (chiefly carbon dioxide - CO₂) to pass from the blood into the surrounding air. Air from the environment enters the respiratory tract when we inhale, and oxygen is taken up into the blood in the lungs. The O₂ is transported mainly by the hemoglobin in red blood cells to every cell of the organism. In the mitochondria of all cells of the organism oxygen becomes involved in the metabolic breakdown of substrate. The CO₂ that is formed in this process is subsequently taken to the lungs dissolved in the blood and carried by the hemoglobin. In the lungs, it leaves the fluid phase and enters the respiratory tract as gas. Exhaling expels the carbon dioxide into the air. *Breathing* takes place in the respiratory tract; *respiration* occurs in every cell of the organism when metabolites are oxidized. The circulating blood insures the transport of gases between the respiratory tract and the cells of the organism.

We will subsequently consider the physiological morphology (the shape and structure) and embryology, the blood supply, the physiology, the regulation, and the function in the organism of the respiratory tract to gain a view of its characteristic place in the organism.

2.2. The Physiological Morphology of the Respiratory Tract

2.2.1. The Shape of the Respiratory Tract

The respiratory tract is divided into an upper and a lower respiratory tract.

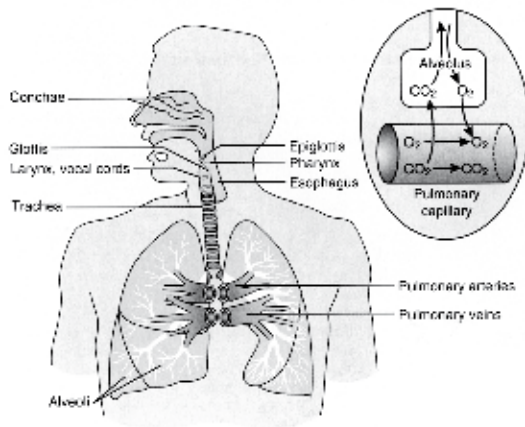


Fig. 2.1. The upper and lower respiratory tract (from Guyton 2000)

The Upper Respiratory Tract

The upper respiratory tract consists of nose, pharynx, and larynx (fig. 2.1.). Several other air-filled spaces in this area, the paranasal sinuses and the middle ear, which directly connect to the nose, pharynx, and larynx, are closely related to the upper respiratory tract. In disease of the upper respiratory tract, the sinuses and middle ear (including the mastoid air cells) may be involved. We will also consider the paranasal sinuses and the middle ear when we discuss the upper respiratory tract. Together they form all the air-filled spaces of the head. Most of the nasal passages, sinuses, and middle ear are embedded in bone. A cartilaginous wall suspends the Eustachian tube. The

pharynx is suspended from the base of the skull.

The entire upper respiratory tract, including the paranasal sinuses and middle ear, is embedded in or suspended from either bone or cartilage.

The Lower Respiratory Tract

The lower respiratory tract is mostly tubular in shape.

- Proximally:
Proximally, the lower respiratory tract consists of the larynx, trachea, and bronchial system (fig. 2.1.), which all have cartilage in their walls. The cartilages of the larynx hold the vocal cords. The larynx is an intricate system of cartilage and muscular cords that form the central organ for speech in humans.
- Distally:
Distally, the lower respiratory tract consists of the respiratory bronchioles (fig. 2.1.).

The alveolar ducts and the alveoli form respiratory units, where the actual gas exchange occurs. The trachea, bronchial system, and the respiratory units together form the lung. There is no bone or cartilage in the tissue of the respiratory units that keeps these essential areas open to the flow of air. They are kept open with the help of the pleura and the chest wall, and the action of "surfactant".

- Pleura:

A layer of visceral pleura covers the lung, and a layer of parietal pleura covers the inside of the thoracic wall. The viscous fluid in the pleural cavity between them permits the lung to glide along the thoracic wall as it is expanding at *inhalation*. The negative intrapleural pressure ensures that the two layers of pleura hold together as the chest expands, and thus enables lung expansion along with chest expansion during inspiration.

- Surfactant:

Surfactant is a surface tension-lowering compound inside the alveoli that prevents the alveoli from collapsing at *exhalation*. The forces that hold together a drop of water would also collapse the alveoli in a gesture of imploding if the surface tension locally were not drastically lowered up to $\frac{1}{12}$ th of its value by a surface active agent in water, such as surfactant (see also section 2.2.2.).

- Other factors influencing the shape of the lower respiratory tract:

The heart is spared out in lung tissue, or rather the lungs grow around the heart phylogenetically. The bronchial tree has special bronchi-associated lymphoid tissue (BALT), which deals with incoming pathogens, since the bronchial tree interfaces directly and intensively with the surroundings.

*The upper part of the lower respiratory tract is held open by cartilage. The respiratory units are kept open by the pull of the thoracic wall during inspiration and by the action of surfactant during expiration. The respiratory units are suspended in the bones and muscles of the thoracic wall. (For further thoughts about the morphology of the respiratory tract see also the Anatomy Module of **BOLK'S COMPANIONS FOR THE STUDY OF MEDICINE**)*

→ The outer shape of the entire respiratory tract is to a large extent dependent on the surrounding structures of skull, spine, ribcage, mediastinum, and diaphragm.

2.2.2. The Structure of the Respiratory Tract

The respiratory tract is mostly a membranous structure that allows the passage and diffusion of air when the processes described above keep it open to the surrounding air.

The membrane-like structure of the respiratory tract repeats itself in the structure of surfactant. Surfactant molecules line the alveolar walls (fig. 2.2.). Surfactant consists mainly of the phospholipid dipalmitoylphosphatidylcholine and some specific proteins. The lipid molecules, which are mostly hydrophobic, arrange themselves such that their hydrophobic tails stick out into the air of the lumen of the alveoli. The specific proteins of surfactant form channels in the lipid layer for the passage of substances. Thus surfactant structure has similarities to the structure of the layers of the membranes in the body.



Fig. 2.2. The apical part of a type II cell with lamellar bodies (LB) being excreted into the surface lining layer (SLL). The alveolar space (A) is lined with a thin black film of dipalmitoylphosphatidylcholine (arrows) (from Fishman 1988)

The type II cells lining the alveolar walls secrete the surfactant. The membrane-like structure of surfactant is replenished when we sigh every few minutes or so, when we yawn, or when the membrane is otherwise stretched out. A special feature of

surfactant is that it allows the surface tension in the alveoli to change in relation to the changes in the alveolar surface area during breathing. Surfactant is a characteristic substance of the respiratory tract and is essential for the mechanics of allowing air to enter the fluid phase. Underneath the surfactant membrane lie intra-alveolar macrophages, which constantly remove surfactant molecules.

The structure of the respiratory tract is characteristically membrane-like. Also, surfactant, a prototypical substance of the lungs, has a membrane-like structure.

→ *The membrane-like structure is characteristic of the respiratory tract.*

2.2.3. Embryology and Development

Macroscopic Development

The development of the upper respiratory tract starts from a different point of origin than the lower respiratory tract. They will be described separately.

Upper respiratory tract

The *nose and paranasal sinuses* develop during the first years of life from and in the plate bones of the head, which have their origin in the neural crest (fig. 2.3.). The sinuses start out as diverticulae of the lateral wall of the nose after birth. The nose and sinuses are not full-grown until after puberty. Then they contribute substantially to the definitive shape of the face.

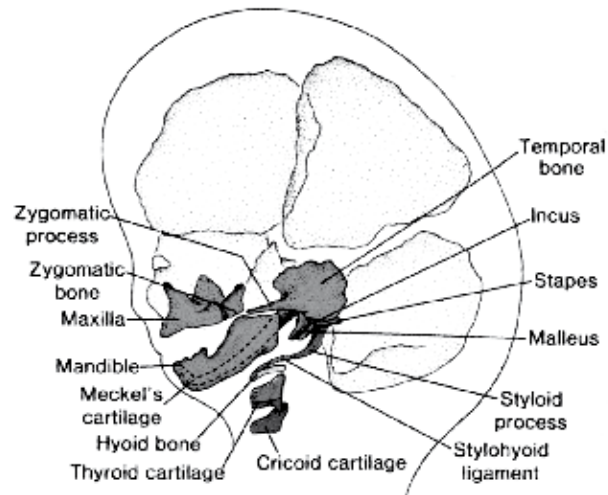


Fig. 2.3. Embryological development of the head in a 4 week old embryo. The darker shaded area originates from the pharyngeal arches (from Sadler 1995)

Then they contribute substantially to the definitive shape of the face.

The area of the *pharynx, larynx, and ear* is almost completely derived from the pharyngeal (or branchial) arches and clefts. This area is phylogenetically related to the gill system in fishes and amphibians. For these, the gas exchange takes place in the area of the gills.

Lower respiratory tract

The lower respiratory tract develops from a diverticulum in the primitive foregut (see also section 3.2.3.). This lung bud forms dichotomous branches in up to 24 generations (fig. 2.4.). The two buds that are formed each time do not have the same diameter. Branching in the pulmonary tree is not a matter of chance but happens according to a definite ordering principle (Goldberger et al 1985).

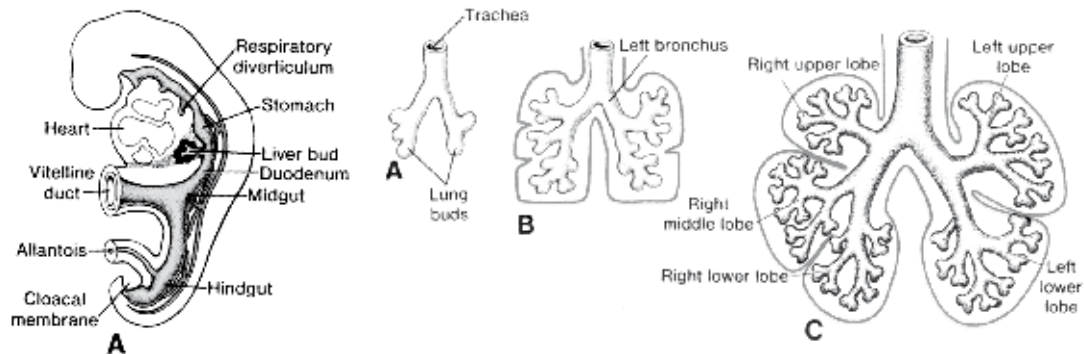


Fig. 2.4. Embryological development of the lower respiratory tract. The development of respiratory diverticulum to lung (from Sadler 1995)

The splanchnic mesoderm surrounding the foregut also surrounds the future trachea and bronchi. It develops into the smooth muscle and cartilage that allows and at the same time restricts the expansion and contraction of this system independently of the pressure in the lungs.

The *larynx* develops where the lung bud is connected to the primitive foregut. The laryngeal cartilages and muscles develop, however, not from splanchnic mesoderm, but originate

from mesenchyme of the 4th and 6th pharyngeal arch. Their innervation and blood supply develop from the innervation and blood supply to these pharyngeal arches.

During the first 10-14 years of life, the *lung* continues a maturation process consisting of further branching of the bronchial system, formation and growth of new alveoli, and thinning of the blood-air barrier. The alveolar surface is about 70 m² in adults. In the newborn it is 2.8 m². The lung is not full-grown until after puberty.

The respiratory tract, including sinuses and middle ear, originates in all 3 different embryological layers:

- *the nose and sinuses develop from **ectoderm** from the neural crest*
- *the middle ear, pharynx, and larynx develop from the **mesoderm** from all 6 pharyngeal arches, covered on the one side by a layer of ectoderm, on the other by a layer of endoderm, whereby the larynx develops at the point of transition between the primitive foregut and the respiratory diverticulum*
- *the bronchial system and respiratory units develop from **endoderm** from the respiratory diverticulum of the foregut*

Development of the Epithelium of the Lower Airways

In the 3rd-4th week after fertilization, during the time that all organs first develop (see also the *Embryology Module* of **BOLK'S COMPANIONS FOR THE STUDY OF MEDICINE**), the budding lung is lined with primordial epithelium that is undifferentiated and cylindrical. It is of endodermal origin, since the respiratory diverticulum buds out from the primitive foregut.

From the 10th-12th week onwards, the trachea and main bronchial system can be easily differentiated from the future respiratory units by the epithelium that lines the walls. It is cylindrical in the main bronchial system; in the respiratory bronchioles it has become cuboidal. The cylindrical cells in trachea and bronchi develop into ciliated cells and mucus producing cells, which will assist the lung in clearing away undesirable particles upward and outward. The lung will be in direct contact with the outside world!

At the end of the 6th month, the cuboidal epithelium includes type II alveolar cells, which produce alveolar surfactant. In the last two months of pregnancy and during the first years of postnatal life, some cuboidal cells become more and more flattened (type I cells), which minimizes the blood-air barrier between the alveoli and the lung capillary network and thus facilitates the transport of gases. The red cell hemoglobin/air distance is only approximately 1.5 mm in the adult.

The epithelium becomes more and more membrane-like in the respiratory units, where effective air exchange has to occur.

→ *The embryology of the respiratory tract shows how it originates from all three embryological layers. In the respiratory units of the lung the epithelium differentiates to allow for its function in gas exchange.*

2.3. Blood Supply to the Lung

The lung has two sources of blood circulation, the bronchial and the pulmonary vessels. The pulmonary system is much larger than the bronchial system.

Bronchial System

The bronchial system supplies the structures of the larger airways and the large pulmonary vessels with oxygen saturated arterial blood. It also warms and humidifies the incoming air. Sympathetic nerves regulate blood flow in the bronchial system.

Pulmonary System

The pulmonary system develops from the artery of the right 6th pharyngeal arch, and supplies the capillary network around the alveoli where the gas exchange occurs. The pulmonary vascular resistance of vessels decreases markedly after birth and is eventually only 10% of the vascular resistance in the systemic circulation. With it the wall thickness of this system decreases also. The capillary network looks more like a thin film of blood, spread out over the outside surface of the alveoli. The film is just thick enough to allow

the passage of red blood cells. The low vascular resistance in the large capillary bed results in a low-pressure system locally.

Pulmonary artery blood is arterial blood with a low oxygen saturation that comes directly from the right ventricle (see also section 5.2.1.). The pulmonary veins take the oxygenated blood from the lungs directly into the left atrium. 10% of the total blood volume is pooled in the pulmonary circulation. The fraction of blood in the lung is 40-50% of its *total weight*. This is higher than in any other organ.

→ *The lung contains the largest amount of blood by relative weight.*

Most of the blood that enters the lungs has low oxygen saturation.

Most of the blood that leaves them has high oxygen saturation.

2.4. Physiology of the Respiratory Tract

2.4.1. The Movement of Air

Physiologically, the respiratory tract can be divided into three areas, which each have a different relation to the *flow* of air. There are areas where the air is mainly absorbed, those where the air is mostly only conducted, and there is the area where the air is exchanged in a process of diffusion.

Air Absorption

In the sinuses, the air hardly moves. Air enters the sinuses passively from the nose through a narrow opening in the lateral nasal wall. A small amount of air in the sinuses is absorbed into the bloodstream. This may result in a negative pressure in the sinus during sinusitis, since the air cannot be replenished from the nose due to swelling of the membranes in the opening between nose and sinus. It may cause much pain in sinusitis.

The middle ear also contains air that does not move much. The air in this area is passively replenished from the pharynx through the Eustachian tube. We may become aware of this phenomenon when we pop our ears. There is some resorption of air from the middle ear, which becomes visible in the retracted tympanic membrane in chronic middle ear infection, when the swollen Eustachian tube does not permit air to enter the middle ear space.

*In the sinuses and middle ear, the air becomes rather static, and some **absorption of air** into the blood takes place.*

Air Conduction and Speech

The nose, pharynx, larynx, and bronchial tree conduct the air. Physiologically, they form a middle area in which the air streams rhythmically back and forth with the breathing. This is the area of the anatomical "dead" space, which comprises 30% of the volume of each breath. Contraction or relaxation of the smooth muscles in the trachea and bronchial system can influence airflow. These smooth muscles are involuntary, and may be influenced by subconscious thoughts and feelings related to stress or anxiety, for example in asthmatic diseases. Clearing the throat, coughing, sneezing, or crying move the air in the respiratory tract too.

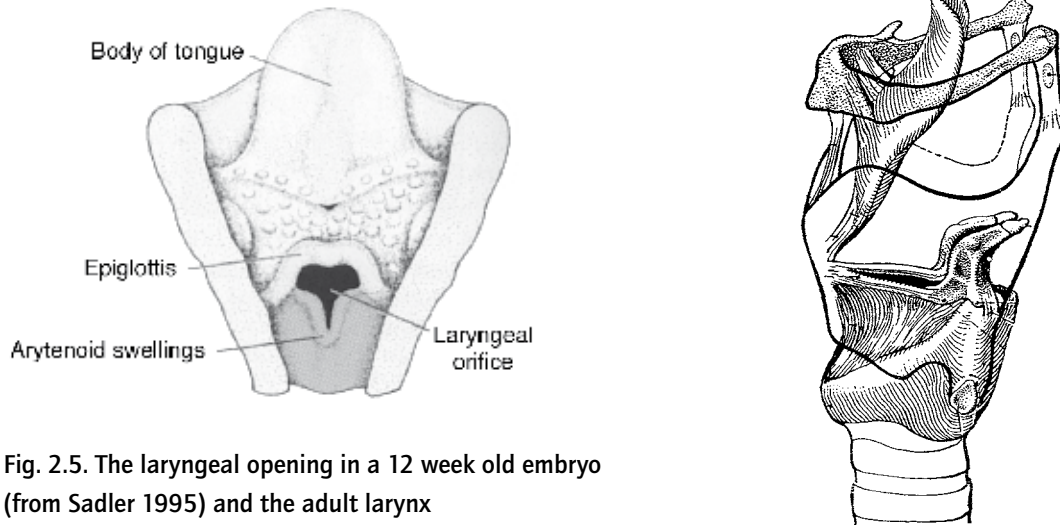


Fig. 2.5. The laryngeal opening in a 12 week old embryo (from Sadler 1995) and the adult larynx

In the middle of the ventilatory dead space, the larynx is situated, which needs the rhythmical movement of the air to function (fig. 2.5.). The vocal cords in humans, with their very specific, mostly muscular structure, influence the flow of air by interrupting it partially or bringing it to a total standstill in many varied and refined ways. The vocal cords are the area where the resistance against the flow of air in the respiratory tract is greatest. The normally inaudible inhaling and exhaling of air then becomes audible in speech. The pharynx is also part of the speech apparatus, and further expands the possibilities of speech. This happens as a result of the descent of the larynx, which results in a lengthening of the pharynx and a position of the tongue that is more dorsal and caudal than in the higher primates. Also the pelvic floor, abdominal muscles, diaphragm, and neck musculature participate in the speech process.

The vocal cords in lower primates are only membranous. In higher primates there is some muscular tissue in the vocal cords (Verhulst 1999).

Speech is an active, conscious process in humans that occurs during expiration in the middle of a part of the respiratory tract where the air is moved passively, rhythmically, and mostly unconsciously.

*The **conduction of air** is predominant in the nasal passages, pharynx, larynx, and bronchial tree. The air current moves continuously and rhythmically on the inbreathing and outbreathing and allows the possibility of speech.*

Air Diffusion

The lower respiratory tract contains the respiratory units where the actual gas exchange occurs. Gas exchange is by diffusion. Diffusion is a *passive* process, whereby the substrates move by way of a pressure gradient, in this case between the gas pressure of the alveolar air and of the blood in the capillary bed. Oxygen and carbon dioxide are gases, and are lipid soluble. This makes their diffusion through the surfactant layer and the alveolar and capillary membrane easy. To assure adequate gas exchange, the capillary surface area of the lung is the greatest of any organ in the body.

The **diffusion of air** is predominant in the lungs' respiratory units. The air again becomes almost static, but only for the moment between inhaling and exhaling, as the current of air turns around.

2.4.2. Breathing

Breathing has two phases, inspiration and expiration.

Inspiration

Airflow in the respiratory tract during inspiration is effected by contraction of the muscles of the chest wall (internal and external intercostals, and the diaphragm), and, in case of need, the accessory muscles of breathing (scalenes and sternocleidomastoids). All muscles are voluntary, striated muscles. They enlarge the chest cavity in a caudal as well as in the fronto-dorsal direction (fig. 2.6.). By means of the existence of a negative intrapleural pressure, the lungs are forced to move along with the chest wall. Chest wall expansion causes an increase of the negative intrapleural pressure and a negative pressure in the respiratory tract and consequently a flow of air from the surroundings via the upper respiratory tract into the lungs.

The inhaling of air is an active process. Muscles surrounding the respiratory tract perform the work. The tissues of the respiratory tract follow the chest wall movements passively.

Expiration

The movement of air in the expiratory phase is largely dependent on the elastic recoil or elasticity of the lungs (80%) and surrounding tissues (20%). That the lungs do not

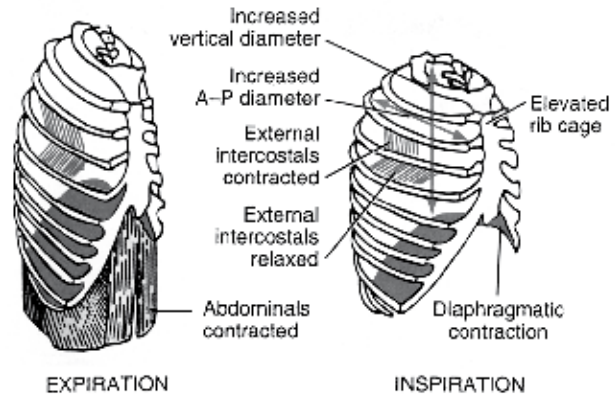


Fig. 2.6. The thoracic cage in inspiration and expiration (from Guyton 2000)

collapse during deflation is in part due to the rigidity of the ribcage and the cartilage around the larger airways and the negative intrapleural pressure. When this pressure becomes positive, for example in pneumothorax as a result of a perforation trauma in the thoracic wall, the lung collapses. The pleura holds the lung connected to the chest wall. Alveolar surfactant molecules play a major role in this phase, assuring that the alveoli do not collapse (see also section 2.2.2.).

The exhaling of air is an overall passive process.

2.4.3. The Rate of Breathing

The rate of breathing in humans varies as a function of the respiratory needs of the tissues. At rest the rate is 16-18 breaths per minute. In walking or running, the rate may vary from one breath for 4 or more steps to one for every 2 steps. The vertebrates in general have to take one breath with each step as they move. This is related to the fact that their thorax muscles and bones also serve as padding against the impact to the spine and nervous system of the contact of the front legs with the ground. They also need the breathing to get rid of excess warmth produced in movement. In humans the eccrine sweat glands take over this function, which frees the lungs further from functions other than breathing (Verhulst 1999). In humans, the lungs are freed from all functions except breathing, which creates the further possibility to develop speech.

→ *Airflow in the respiratory tract as a whole is not caused by the respiratory tract itself, but by surrounding muscles and the elastic recoil of tissues. Airflow itself is a passive event. Only in the larynx we find muscles that actively and voluntarily control the flow of air against the flow of normal breathing. This forms the basis for the capacity of speech, which is only present in humans.*

2.4.4. Digestion and the Respiratory System

The air that passes through the respiratory tract is *physically* warmed up, partially cleaned, and humidified in the nose, pharynx, and bronchi to match the temperature and humidity level in the alveoli, where gases from the air will enter the bloodstream. This process of equilibration happens very rapidly, and, even when the air is inhaled through the mouth, is accomplished by the time the air reaches the distal bronchi.

We could compare this to the activity of the digestive tract, which has to transform food rather than air such that it can enter the bloodstream. In order to do this, enzymes are formed and secreted at different levels to break down the foodstuffs *chemically* and bile is secreted to allow the hydrophobic lipids to be taken up in the aqueous milieu of the blood. In addition the food is physically warmed up, partially cleaned, and liquefied.

The epithelium in the alveoli of the lung produces surfactant actively (section 2.2.2.). The epithelium of the bronchi, trachea, larynx, pharynx, and nose produces mucus. The capillary endothelium in the lung metabolizes some substances, the most important of which is angiotensin I from the liver. It converts angiotensin I into its active metabolite angiotensin II, which is a strongly vasoactive hormone (see also sections 3.5.2. and 4.5.).

The physical warming, cleaning, and humidifying of air before it enters the bloodstream in the respiratory tract, and its secretion of mucus, is a relatively passive occurrence compared to the production and activity of digestive secretions and the movement of food in the intestines.

→ *The physiology of the respiratory tract is characterized by relatively passive events. The exception to this is the active production of surfactant in the alveoli.*

2.5. Regulation of Respiration and Pulmonary Circulation

Respiration is mainly regulated through different centers of the central nervous system and the vagus nerves (fig. 2.7.). Excess carbon dioxide or excess hydrogen ions (low pH) in the blood directly affect the respiratory center to increase the breathing rate. Stretch receptors in the walls of the airways affect the breathing through respiratory centers in the central nervous system via afferent fibers of the vagus nerves.

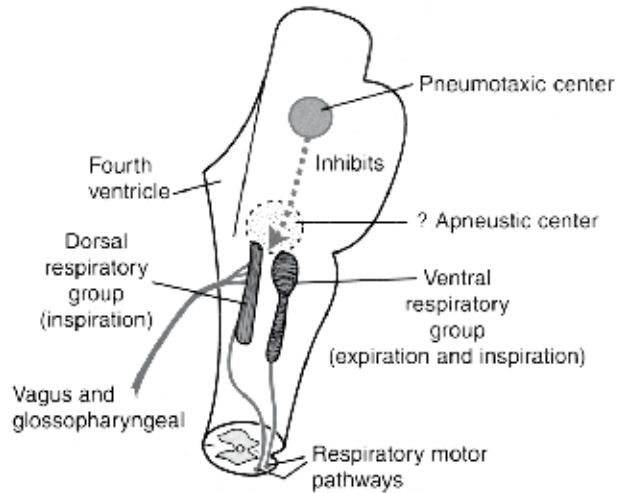


Fig. 2.7. The respiratory centers in the brain stem (from Guyton 2000)

Oxygen saturation affects peripheral chemoreceptors in carotid and aortic bodies in the respective arteries, which in turn transmit the signal to the respiratory center.

Alveolar circulation is diminished when oxygen saturation in the alveolus falls. Increased cardiac output, as in exercise, increases the pulmonary circulation up to sevenfold by opening extra capillaries so that the total volume of the capillary bed increases. Local pressure in the capillaries changes very little with increased cardiac output.

→ *The regulation of respiration comes chiefly from outside the respiratory tract, via the nervous system.*

2.6. The Function of the Respiratory Tract and the Lung

The function of the respiratory tract is to facilitate the streaming of air into and out of the organism. Oxygen and carbon dioxide are essential in metabolism. Oxygen plays an important role in the catabolic processes of cells as it allows the energy of hydrogenated molecules such as the reduced form of nicotinamide adenine dinucleotide (NADH) to be transferred to energy carriers like adenosine triphosphate (ATP). This is accompanied by the formation of water. Carbon dioxide is the most abundant end product of catabolism.

2.7. Conclusion

The respiratory tract is able to fulfill its function, supplying the organism with the necessary oxygen for (catabolic) combustion processes and excreting gaseous waste products (chiefly carbon dioxide), mainly by creating the conditions to make this possible rather than by actively pursuing its goals.

- Morphology:
The membrane-like respiratory tract is largely supported and shaped *passively* by surrounding bone, muscle, or cartilage. The alveoli keep their *passive* shape in expiration through the action of surfactant. *The respiratory tract is membrane-like in structure and completely supported from without. This is the most characteristic feature of the respiratory tract.*
- Blood supply:
The pulmonary artery blood supply contains blood low in oxygen saturation. Up to 50% of the lung weight is blood.
- Physiology:
The physiology of the respiratory tract is dominated by *passivity* on the part of the respiratory tract: the necessary movement of air is effected by surrounding muscles for the inhaling, and by the elastic recoil of the lung tissue for the exhaling. Gas exchange takes place through the *passive* process of diffusion on the basis of pressure gradients in the upper respiratory tract as well as in the alveoli. The modification that the air

	Lung + Respiratory Tract	Liver	Kidneys	Heart
Morphology	Shape from without, tubular organ, membranous structure			
Blood supply	50% of <i>weight</i> is blood, largely O ₂ unsaturated, capillary blood in thin film			
Physiology	Passive diffusion			
Regulation	Mainly from without, via the central nervous system			
Function	Passive supplying			
Characteristic	Membrane-like structure, <i>diffusion of gases</i> (O ₂ and CO ₂) and water			

undergoes in the respiratory tract is very mild compared to the changes the food has to undergo before it can enter the blood stream in the digestive tract.

- Regulation:

The respiratory tract ventilation and perfusion are regulated mainly *from without* through the nervous system via the carbon dioxide- and oxygen-concentrations, the pH of the blood, and the cardiac output.

- Function:

The function of the respiratory tract is *passive* in that it supplies the organism with needed gases, without doing much with them itself directly.



→ *The respiratory tract is an overall passive system. It is constantly in movement but it is moved along, rather than actively moving itself. Its membrane-like structure is its most characteristic feature.*

The passivity in the respiratory tract is overcome in the **larynx**, especially in humans. The human larynx actively shapes the air to become the carrier of sound by bringing it to a relative standstill. This is refined by the action of the muscular activity of the vocal cords and the pharynx, including the tongue, and is supported by many other muscles in the body. The speech apparatus develops in the part of the respiratory tract that is considered physiological and anatomical "dead" space.

Physiology

Organphysiology from a Phenomenological Point of View

Can physiology give more insight into the living human organism than the mere facts reveal at first? Is the level of activity the same for all organs? Are the vital qualities at work in organs unique for organisms and limited to biological activity? Can we find a scientific basis to research the coherence between organ systems?

By enhancing the current scientific method with phenomenological points of view we can find meaning in the facts and understand them as an expression of life itself. The phenomenological method makes the relation between organs visible and comprehensible. It approaches scientific facts from the point of view of their coherence and can give totally new insights this way.

What emerges is a grasp of the interrelations between biological processes, consciousness, and nature.