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Chapter

Introductory Chapter: Respiratory Physiology

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1. Introduction: What is physiology?

Physiology is the link between the basic sciences and medicine. It integrates the individual functions of all the body's different cells, tissues, and organs into a functional whole, the human body. Understanding the principles of physiology can help us explain the physical and chemical mechanisms that are responsible for the origin, development, and progression of life. Each type of life is from the simplest virus to the largest tree or the complicated human being. The science of *human physiology* attempts to explain the specific characteristics and mechanisms of the human body that make it a living being. The fact that we remain alive is the result of complex control systems. Ultimately, the functions of cells, tissues, and organs must be coordinated and regulated. All of these functions are the essence of the discipline of physiology [1, 2].

Physiology studies dynamic processes of life from the simplest molecules, organelles, cells, tissues to the complex organs and organ systems. The discipline of physiology has been closely interconnected with medicine. Structure and function are related to each other – as in case of anatomy, histology, structural biology and physiology [3].

Medical physiology deals with how the human body functions. Countless molecules, subcellular organelles, cells, tissues, organs and organ systems work coordinately to maintain the homeostasis of a body. It is essential to take a global view of the human body, considering every level of the organizational unit.

Classification of physiology could be according to the organ systems. For many practicing clinicians, physiology may be the function of an individual organ system, such as the cardiovascular, respiratory, or gastrointestinal system. Others focus on the cellular principles that are common to the function of all organs and tissues. This last field has traditionally been called general physiology, but nowadays the term of cellular and molecular physiology.

As a discipline of physiology evolves and new information emerges, there is a tendency to integrate physiological concepts from the level of DNA and epigenetics to the human body, and everything in between [4].

Physiological genomics is the link between the organ and the gene. The grand organizer—the master that controls the molecules, the cells, and the organs and the way they interact—is the genome with its epigenetic modifications. Physiological genomics (or functional genomics) is a new branch of physiology devoted to the understanding of the roles that genes play in physiology [3].

Some important aspects of physiology remain as fundamentally important today as when the pioneers of physiology discovered them a century or more ago. These early observations were generally phenomenological descriptions that physiologists have since been trying to understand at a mechanistic level. In his lectures on the phenomena of life, Claude Bernard noted in 1878 on the conditions of the constancy of life. Claude Bernard introduced the concept of "milieu intérieur" – internal environment. He stated that animals have two environments: the "milieu extérieur" that physically surrounds the whole organism and the "milieu intérieur," in which the tissues and cells of the organism live. The internal environment surrounds and bathes all the anatomic elements of the tissues, the lymph or the plasma. This internal environment is what we today call the extracellular fluid.

Another theme developed by Bernard was that the "fixité du milieu intérieur" (the constancy of the extracellular fluid) is the condition of "free, independent life." Homeostatic mechanisms—operating through sophisticated feedback control mechanisms—are responsible for maintaining the constancy of the milieu intérieur. Homeostasis is defined as a self-regulating process by which an organism maintains internal stability in a constantly changing external condition. Homeostasis regulates the processes in the body in the way that returns critical systems of the body to a set point that is necessary for the organism to survive [3, 5].

Medicine borrows its physicochemical principles from physiology. Study of physiological system structure and function, as well as pathophysiological alterations, has its foundations in physical and chemical laws and the molecular and cellular makeup of each tissue and organ system. If you know how organs and organ systems function in the healthy person, you will find out which components may be malfunctioning in a patient.

2. The importance of respiration

Life starts with breathing. As it was written in the Bible God "breathed into Adam's nostrils the breath of life" and then used part of Adam's ventilatory apparatus – a rib – to give life to Eve. Hippocrates suggested that the primary purpose of breathing was to cool the heart. In the 18th century the true role of breathing began emerged. By the end of the 18th century, chemists and physiologists studied the chemistry of gases and appreciated that combustion, putrefaction, and respiration all involve chemical reactions that consume O_2 and produce CO_2. Boyle, Henry, Avogadro, and others subsequently stated the theoretical foundation for the physiology of O_2 and CO_2. Considering the recent scientific advances, respiration was defined as process, when energy was produced with the intake of oxygen and the release of carbon dioxide.

Later work showed that mitochondrial respiration is responsible for the O_2 consumption and CO_2 production observed by Spallanzani. This aspect of respiration is often called **internal respiration** or oxidative phosphorylation. Respiratory physiology focuses on **external respiration,** the dual processes of (1) transporting O_2 from the atmosphere to the mitochondria and (2) transporting CO_2 from the mitochondria to the atmosphere. CO_2 transport is intimately related to acid-base homeostasis.

Traditionally the process of respiration is divided into three phases: (1) cellular respiration, (2) transport of respiratory gases and (3) ventilation of the gas exchange organs (breathing) [6].

The main goals of respiration are oxygen uptake and elimination of carbon dioxide. Secondary goals include acid-base buffering, hormonal regulation, and host defense. To achieve the goals of respiration, three main functional components of the respiratory system are used: (1) mechanical structures, (2) membrane gas exchanger and (3) regulatory system (network of chemical and mechanical sensors throughout the circulatory and respiratory systems). All three components are tightly integrated, and dysfunction of one can lead to respiratory distress or failure [7].

Different kinds of neural receptors are present in the respiratory airways, lungs and pulmonary blood vessels:

- Changes in lung volume are perceived by pulmonary stretch receptors and muscle spindles.

- Rapidly adapting irritant receptors respond both to changes in lung volume and to the presence of chemicals such as histamine, prostaglandins, and exogenous noxious agents.

These receptors send the signals to the respiratory centers in the brain via the vagus nerve. On the other hand, the respiratory centers affect the breathing pattern by increasing the respiratory rate and/or stimulating cough, bronchoconstriction, and/or mucus production [8].

Input from these neural receptors likely accounts for the hyperventilation and hypocapnia that can occur in patients with pulmonary fibrosis even when hypoxemia is reversed by the administration of oxygen. Hyperventilation may occur by this mechanism in patients with such problems as asthma, interstitial lung disease, pulmonary edema, pneumonia, and pulmonary embolism.

Respiratory centers in the medulla receive stimulatory input from central respiratory pacer cells, central and peripheral chemoreceptors, upper airway receptors, other areas of the brain, and volitional pathways and integrate these signals into a combined output to respiratory muscles to modulate breathing frequency, inspiratory time, and expiratory time.

2.1 Developmental considerations

Significant changes occur in respiratory physiology during the transition from infancy to childhood, with the development of chest wall structures and maturation of the airways and lung parenchyma. Infancy is a time of rapid changes of central nervous system, neural respiratory control, as well as developmental plasticity and vulnerability. Rib cage geometry becomes more adult-like by about 3 years of age. The high chest wall compliance of the newborn decreases with age and becomes approximately equal to lung compliance, as in adults, by the second year of life, resulting in higher resting lung volume. These changes are important to recognize in the clinical setting because infants are more vulnerable to many disease states due to higher chest wall compliance, immature control of respiration, and increased airway resistance [9].

2.2 Nonrespiratory functions of the respiratory system

The main function of the respiratory system is gas exchange. However, the lung performs several nonrespiratory tasks. These functions include: its own defense against inspired particulate matter, the storage and filtration of blood for the systemic circulation, the handling of vasoactive substances in the blood, and the formation and release of substances used in the alveoli or circulation.

There are several ways in which respiratory system prevents from invading pathogens compromising the upper airway. Mucociliary clearance provides a strong physical barrier, several proteins, antimicrobial peptides, and reactive oxygen species, such as nitric oxide, play a significant role in preventing infection. The upper respiratory tract also has the ability to sense invading pathogens through Toll-like receptors and taste receptors that initiate immune responses [10, 11].

3. Conclusion

Considering all aspects of respiratory physiology, we can assume that with every breath we take, we provide the organism with a power to maintain homeostasis. The body carefully controls endless list of vital parameters and is always ready to adapt to changing circumstances.

Application of essential principles of physiology and staying up to date to constantly changing knowledge in the field is a bridge to treating a patient. Remembering physiological and pathophysiological mechanisms and their impact on health and disease will help the practitioners throughout their professional careers.

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