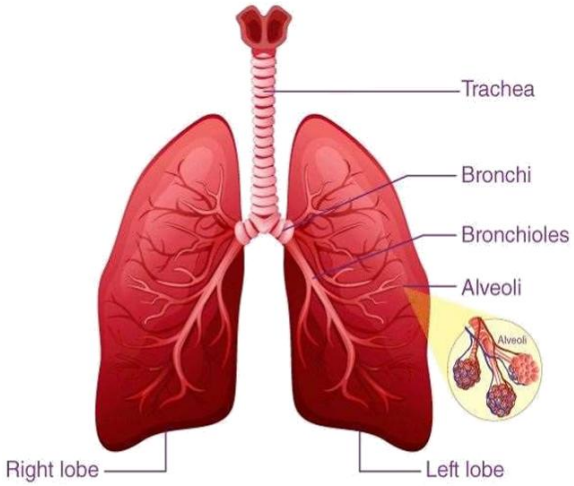
Madenat Alelem University

College of Pharmacy

Medical physics

Physics of lungs and breathing



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Diffusion: is the process of moving a substanceمادّة from the region of higher concentration to the region of lower concentration, spread uniformly (See figure 1). In the process, the molecules of one substance mix with the molecules of the other substance. Molecular diffusion is the thermal motion of all particles at temperatures above absolute zero. The rate of this movement is a function of **temperature**, the **viscosity of the fluid**, and the **size** (mass) of the particles.

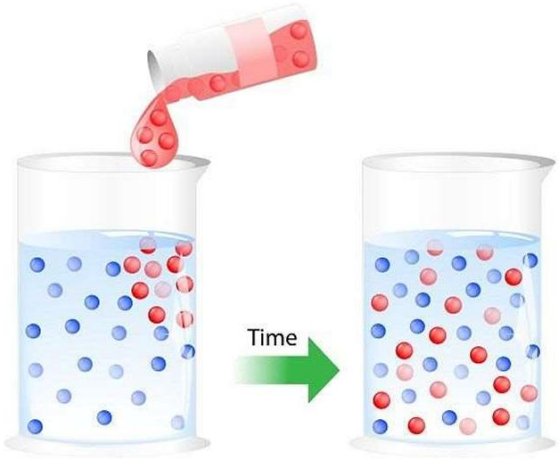

Figure (1): Shows the Diffusion presses.

NOW, what is Diffusion in Biology?

In cell biologyفي علم الأحياء الخلوي , diffusion is the main form of transport for necessary materials, such as amino acids, within cellsداخل الخلايا . Metabolism and respiration rely in part on diffusion. For example, in the alveoli الحويصلات الهوائية of mammalian ثديات lungs, due to differences in partial pressure, oxygen diffuses into the blood and carbon dioxide diffuses out. Lungs contain a large surface area to facilitate this gas exchange process. Figure 2 shows the diffusion process in the cell. Diffusion of solvents, such as water, through a semipermeable شبه نفّاذ membrane غشاء is classified as "**Osmosis**." التناضح

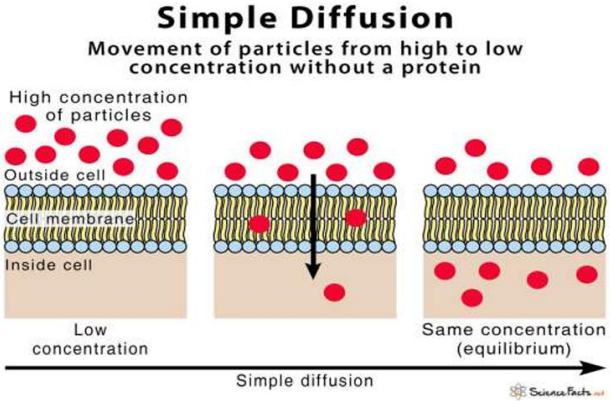

Figure (2): Shows the Diffusion Process in the cell

Physics of Gas Diffusion:

The movement of gases in a contained space (in this case, the lungs) is random. However, overall diffusion results in movement from areas of high concentration to those of low concentration. The collision of the molecules of gas with the sides of the container results in pressure. This is defined by the ideal gas law, given in the following equation:

$$PV = nRT \quad (1)$$

Where: P: is the pressure V: is the volume n: is the amount of substance R: is the ideal gas constant T: is the temperature.

Respiratory System:

Respiratory System: is a biological system consisting of specific organs and structures used for gas exchange in humans, animals, and plants. Figure 3 shows the respiratory system. The function of the respiratory system is:

▼ To extract oxygen from the atmosphere and transfer it into the bloodstream مجرى الدم

▼ To release carbon dioxide from the bloodstream into the atmosphere, these two processes are called "**gas exchange.**"تبادل الغازات

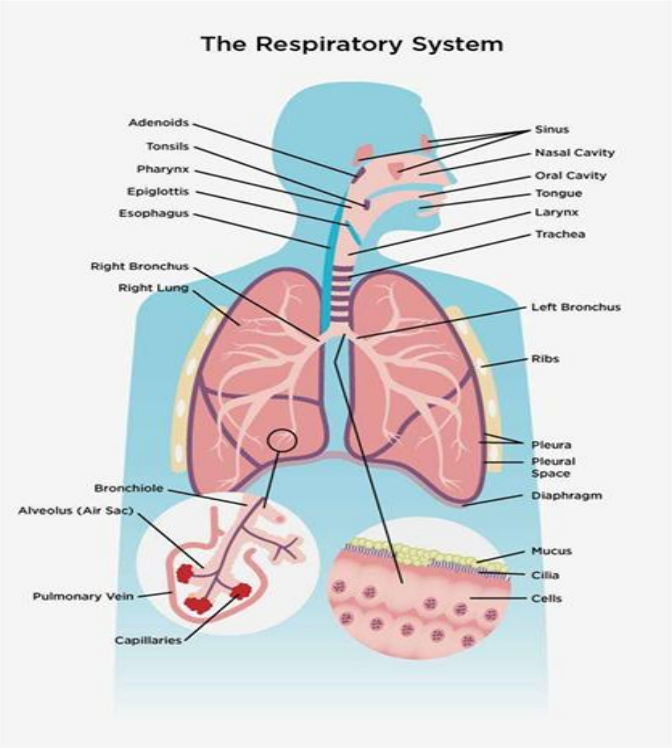

Figure (3): Shows the Respiratory System.

The process that brings oxygen in the air into your lungs and moves oxygen through your body is called "**Breathing**." Our lungs remove the oxygen and pass it through our bloodstream, where it's carried off to the tissues and organs that allow us to walk, talk, and move. Our lungs also take carbon dioxide from our blood and release it into the air when we breathe out.

The Physics of Exchanging Gas between the Lungs and the Blood:

The process through which gases are exchanged between blood and bodily tissues is the diffusion. The transfer of O_2 and CO_2 into and out of the blood is controlled by the **physical law of diffusion**. All molecules are continually in motion. In gases and liquids, and to a certain extent even in solids, the molecules do not remain in one direction. Molecules of a particular type diffuse from a region of higher concentration to a region of lower concentration until the concentration is uniform. Respiratory gas is transported to each and every cell by blood. Tiny capillaries الشعيرات الدموية الصغيرة provide the blood flow to even remote parts of the body tissue. Then the gases (O_2 from the blood to the tissue fluid and CO_2 from the tissue fluid to the blood) diffuse. The diffusion takes this particular direction due to differences in the concentration of these gases.

NOW, how can Gas Exchanges occur? The physics of exchanging gas between the lungs and the blood can be done using:

1. **Dalton's Law of Partial Pressures** الضغوط الجزئية : states that the total pressure exerted مبذولة by a mixture of gases is the sum of the pressures exerted by each gas in the mixture, and the pressure exerted by each gas (its partial pressure) is proportional to the percentage of that gas in the mixture.

$$Pt. = P(CO_2) + P(O_2) + P(N_2) + P(H_2O)$$

2. **Henry's Law**: states that when a mixture of gases is in contact with a liquid, each gas will dissolve in the liquid in proportion to its partial pressure بما يتناسب مع ضغطها الجزئي. The solubility قابليّة الذّوبان of the gas has something to do with how well that actually goes (and there is a temperature effect as well; gases are less soluble at higher temperatures than at lower temperatures).

The Interaction between Blood and Lungs:

Blood is pumped from the heart to the lung under relatively low pressure~ 20 mmHg; the blood volume is about 1 litter (1/ 5 of the blood body supply) to the

lungs, but only 70 ml of the blood is in the capillaries of the lungs to make blood gas exchange.

Physics of Common Lung Diseases:

Emphysema انتفاخ الرئة : is the division between alveoli الانقسام بين الحويصلات الهوائية breaking down produces large lung spaces; this destruction of lung tissue reduces the springiness مرونة of the lungs. The lungs become more constricted ضيّق ; a small change in pressure produces a larger than normal change in volume. Emphysema produces two changes: The lungs become flabby مترهّل and expand. The tissues do not pull very hard on the airways, permitting the narrowed airways to collapse easily during expiration. لا تسحب الأنسجة المسالك الهوائية بقوة، مما يسمح للممرات الهوائية الضيقة بالانهيار بسهولة أثناء الزفير.

Laminar and Turbulent Flow in Liquid:

Laminar Flow التدفق الانسيابي : is a type of fluid (gas or liquid) flow in which the fluid travels smoothly or in regular paths, in contrast to **turbulent flow**. Turbulent Flow is the type of fluid flow in which the fluid undergoes irregular fluctuations or mixing. In turbulent flow, the speed of the fluid at a point is continuously undergoing changes in both magnitude and direction. Figure 4 shows the difference between laminar and turbulent flow.

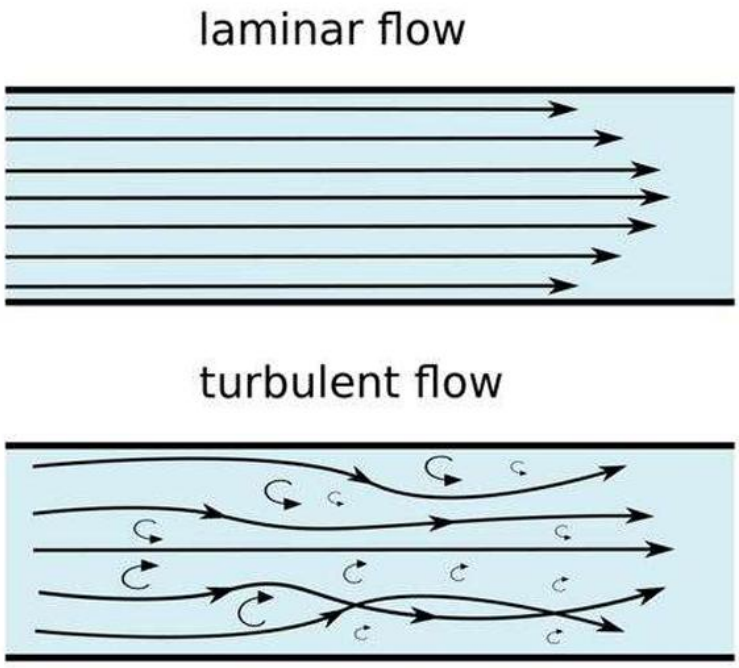

Figure (4): Shows the difference between laminar and turbulent flow.

NOW, what are the characteristics of Laminar and Turbulent flow? Laminar flow is quiet, slow-moving water characterized by water particles moving in a straight, direct line within parallel layers. Turbulent flow, on the other hand, is louder, faster-moving water characterized by erraticallyبشكل عشوائي moving water particles that mix between the parallel layers.

Question: Which is better, Laminar or Turbulent Flow? Turbulent flow is a flow regimeنظام characterized by chaotic فوضوي property changes. This includes a rapid variation of pressure and flow velocity in space and time. In contrast to laminar flow, the fluid no longer travels in layers, and mixing across the tube is highly efficient.

Example of Laminar Flow and Turbulent Flow:

→ **Laminar**: An example of laminar flow is the flow of water in a pipe. The water flows in parallel layers with no disruption between them.

→ **Turbulent**: An example of a turbulent flow is the flow of water in a river. The water flows chaotically around obstacles in the flow.

Upper Respiratory Tractالجهاز التنفسي العلوي

Sinusesالجيوب الأنفية
Air-filled cavities in the skull that lighten the head, warm and humidify inhaled air, and enhance voice resonance. تجاويف مملوءة بالهواء في الجمجمة تعمل على تفتيح الرأس وتدفئة وترطيب الهواء المستنشق وتعزيز الرنين الصوتي.

Nasal Cavityتجويف الأنف
The primary passage for air entry; filters dust and pathogens, warms, and humidifies incoming air.الممر الأساسي لدخول الهواء؛ يقوم بتصفية الغبار ومسببات الأمراض، وتدفئة وترطيب الهواء الوارد .

Oral Cavityالتجويف الفموي
An alternative airway for breathing, especially during high oxygen demand. مجرى هوائي بديل للتنفس، خاصة أثناء ارتفاع الطلب على الأكسجين.

Adenoidsالزوائد الأنفية
Lymphoid tissue located behind the nasal cavity; part of the immune system that traps pathogens. الأنسجة الليمفاوية الموجودة خلف تجويف الأنف، وهي جزء من الجهاز المناعي الذي يحبس مسببات الأمراض.

Tonsilsاللوزتين
Masses of lymphoid tissue at the back of the throat that help fight infections. كتل من الأنسجة الليمفاوية في الجزء الخلفي من الحلق تساعد في مكافحة العدوى.

Pharynxبلعوم
A muscular tube connecting the nasal and oral cavities to the larynx; common pathway for air and food.أنبوب عضلي يربط تجاويف الأنف والفم بالحنجرة، وهو مسار مشترك للهواء والطعام .

Tongueلسان
Muscular organ that assists in speech, swallowing, and helps direct air and food. عضو عضلي يساعد في الكلام والبلع ويساعد في توجيه الهواء والطعام.

Epiglottisلسان المزمار
A flap of cartilage that closes the airway during swallowing to prevent food entering the lungs.رفرف غضروفي يغلق مجرى الهواء أثناء البلع لمنع دخول الطعام إلى الرئتين .

Larynx (Voice Box)(الحنجرة (صندوق الصوت
Contains vocal cords; allows sound production and maintains an open airway. يحتوي على الحبال الصوتية، ويسمح بإنتاج الصوت ويحافظ على مجرى الهواء مفتوحًا.

Lower Respiratory Tractالجهاز التّنفّسي السّفلي

Trachea (Windpipe) القصبة الهوائية
A rigid, C-shaped cartilage-supported tube that conducts air from the larynxحنجرة to the bronchi.الشعب الهوائية

Right Bronchusالقصبة الهوائية اليمنى
Main airway branch directing air to the right lung. فرع مجرى الهواء الرئيسي يوجه الهواء إلى الرئة اليمنى

Left Bronchusالقصبة الهوائية اليسرى
Main airway branch directing air to the left lung. فرع مجرى الهواء الرئيسي يوجه الهواء إلى الرئة اليسرى.

Bronchiolesالقصبات الهوائية
Small branching airways within the lungs that regulate airflow and lead to alveoli. مجاري هوائية متفرعة صغيرة داخل الرئتين تعمل على تنظيم تدفق الهواء وتؤدي إلى الحويصلات الهوائية.