Respiratory ITA Basic Sciences

Chapter: Introduction

Introduction

Teacher's Comment: This session is an on-line tutorial to introduce you to important concepts in respiratory anatomy and physiology. You can complete it during the ITA allotted time (when a supervisor will be available to answer questions and go over concepts) or in your own time before the end of this week.

This resource is designed to guide you through key concepts to support your learning, but the information is not exhaustive and reading around the subjects will be necessary for greater understanding.

We have used external links as learning resources. We have indicated which parts are most relevant, but feel free to explore any resources as you choose. You may find that certain aspects will be relevant to other modules (such as cardiology and ENT).

There is also an on-line formative assessment related to all of this week's teaching which will be available at the end of the week in Blackboard so that you can check your understanding of this week's teaching. You'll also find some additional formative questions on Dundee Chest.

Chapter: Basic Anatomy

Respiratory Tract

The RESPIRATORY TRACT extends from the nose all the way down into the lungs.

Structures include:
- The nose
- The pharynx
- The layrnx
- The trachea
- The bronchial tree
- The lungs

We're going to start with a review of the anatomy of some of the key features of the repsiratory tract by working through some anatomy tutorials on the GET BODY SMART site. (Click here to access)

Make sure you complete the following anatomy tutorials on the Get Body Smart site, clicking on words in blue to animate the diagrams and use the <<Next/Back>> buttons to advance/return between slides and adjacent tutorials. To return to the main menu from a tutorial click 'RESPIRATORY SYSTEM' at the top of the page.

- Major zones and divisions
- The larynx (7 sections)
- The trachea and bronchi (4 sections)
- The lungs, bronchioles and pleurae (9 sections)

You DO NOT need to do the anatomy tutorials for 'the nose and nasal cavity' or 'the phaynx' or the 'physiology tutorials' at this session. Please feel free to explore the other tutorials in your own time throughout the week.

Anatomy Review

Now take a look at this short video giving an overview of the anatomy lungs with Professor Peter Abrahams from Warwick University. (If you would like your own copy of this video and other similar videos you can download it from iTunes-U)

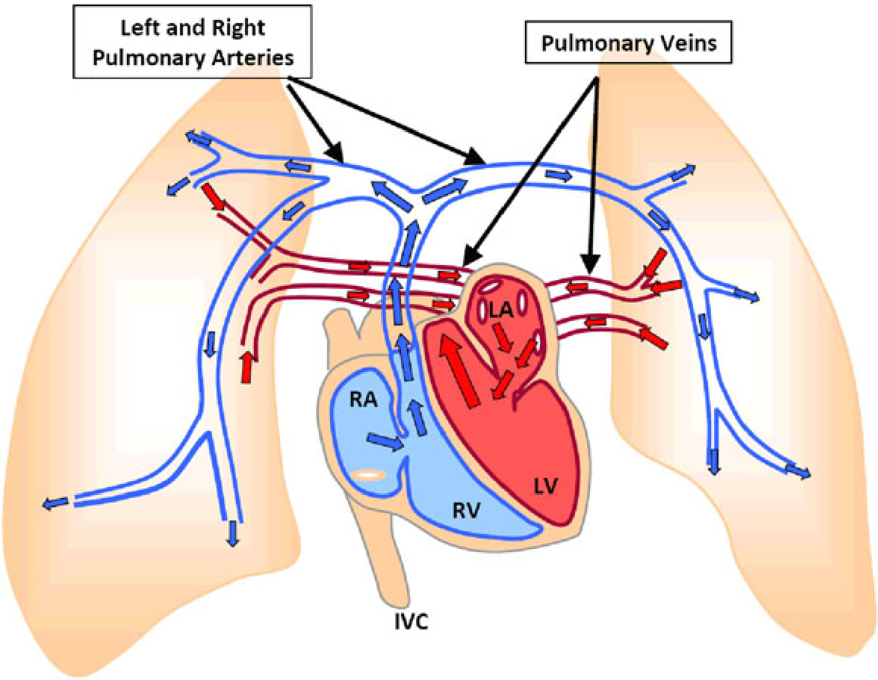
To re-enforce your understanding of the anatomy complete the drag and drop quiz on the pictures in the following link by dragging the correct names to the correct boxes. If the label is correct it will stay in place, if not it bounces back.

Under Section 2 Thoracic Interactive Exercises select and complete sub-section 2 Regional anatomy of thorax - there are 6 items to complete. Click here to access the quiz.

Veascular Supply of the Lungs

The pulmonary trunk divides into the pulmonary arteries. They take deoxygenated blood to the lungs. The pulmonary arteries subdivide many times, following the airways until they reach the alveoli. Here they form capillary beds to exchange gases across the respiratory membrane. The capillaries join up and return to the hilum as pulmonary veins. They carry oxygenated blood to the left atrium of the heart.

The blood supply to the bronchi is supplied by the bronchial arteries (which branch from the descending aorta). They drain to the azygous vein on the right and the superior intercostal vein on the left.



Chapter: Ventilation

Respiration

Respiration simply means the exchange of gases (usually oxygen and carbon dioxide).

Respiration in the lungs is called 'external respiration'.

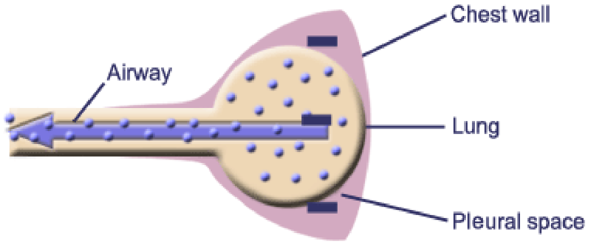
Respiration in the cells is callled 'internal respiration' (cellular biochemistry).

Ventilation is the movment of air in and out of the lungs.

Inspiration is the movement of aire into the lungs.
Expiration is the movement of air out of the lungs.

Inspiration 1

INSPIRATION is an active process which requires muscle contraction. For air to move into the lungs and bronchial tree a neagtive pressure is created (air will flow from an area of high pressure to an area of lower pressure). Negative pressure is made by increasing the volume of the thorax.



Click here to animate

Teacher's Comment: **Take some deep breaths in and as you do so think about the following. Remember the new structure and muscles you learned about in the anatomy section.**

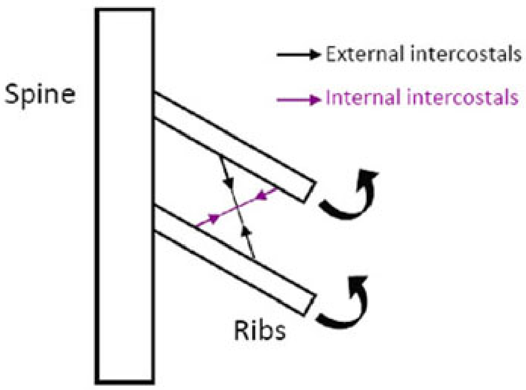
Multiple Choice Question: **How do your ribs and chest wall move as you breathe in?**

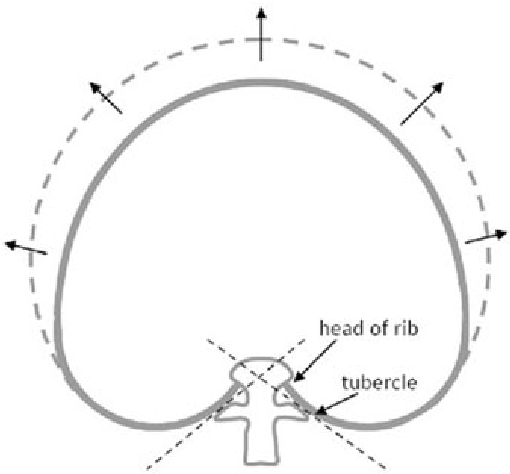
Possible answers:

1. **The ribs move up and out**
2. **The ribs move up and in**
3. **The ribs move down and out**
4. **The ribs move down and in**

The Ribs

The Ribs
The ribs must rotate on an axis joining the tubercle and the head of the rib. The lower, down sloping riibs move upwards, pushing the sternum up and out to increase the AP diameter further (this is often likened to a 'pump handle'). These lower ribs can move out as well as up as their necks and costal cartilage slope down and forwards. The first four ribs can only move up as the coastal cartilage here is short and lies horizontally.





Axis of Rotation

Multiple Choice Question: **To inspire, a negative pressure must be made in the thorax. How can this be achieved**

automatically (i.e. what articulations/movements are required of the bones and muscles involved)?

Possible answers:

1. The diaphragm contracts and moves upwards
2. The diaphragm relaxes and moves upwards
3. The diaphragm contracts and moved downwards
4. The diaphragm relaxes and moves downwards.

The Diaphragm

The diaphragm is the most important muscle of respiration. It is supplied by the Phrenic nerve and cervical nerve C 3, 4 and 5. In its resting position, the diaphragm bulges up into the thorax. On inspiration it flattens (thus increasing vertical thoracic diameter).

As the diaphragm descends, the ribs are pulled up by the external intercostal muscles (which slope down and forwards) to increase both their anteroposterior (AP) and lateral diameters. The intercostal muscles (see earlier) also prevent indrawing during inspiration.

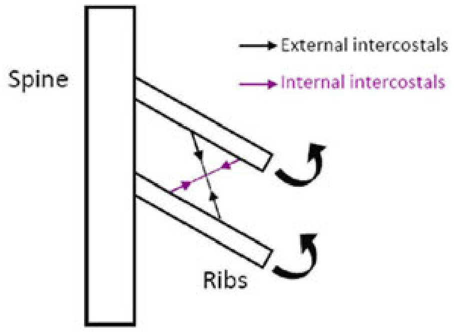


Image caption:
The diaphragm's descent is limited by its attachment to the pericardium above and the abdominal viscera below. In normal breathing it moves about 1cm, but in forced breathing it can move as much as 10cm.

When neurological control is lost, the diaphragm moves in the opposite way – up into the chest on inspiration (towards the negative pressure). It will also move into the chest on lying flat.

Expiration

EXPIRATION is usually a passive process which relies on the elastic properties of the respiratory system. In forced expiration additional muscles and effort are required.

Teacher's Comment: Take a few more deep breaths but this time overemphasize the movements to fill and empty your lungs completely, concentrating on which muscles are used.

Multiple Choice Question: Which additional muscles could come into play to help when breathing is difficult or tiring? (It may help to think of a breathless patient you have seen, their posture and breathing is a result of using these extra muscles)

Possible answers:

1. Pectoralis major
2. Sternamastoid
3. Abdominal wall muscles
4. Latissimus dorsi

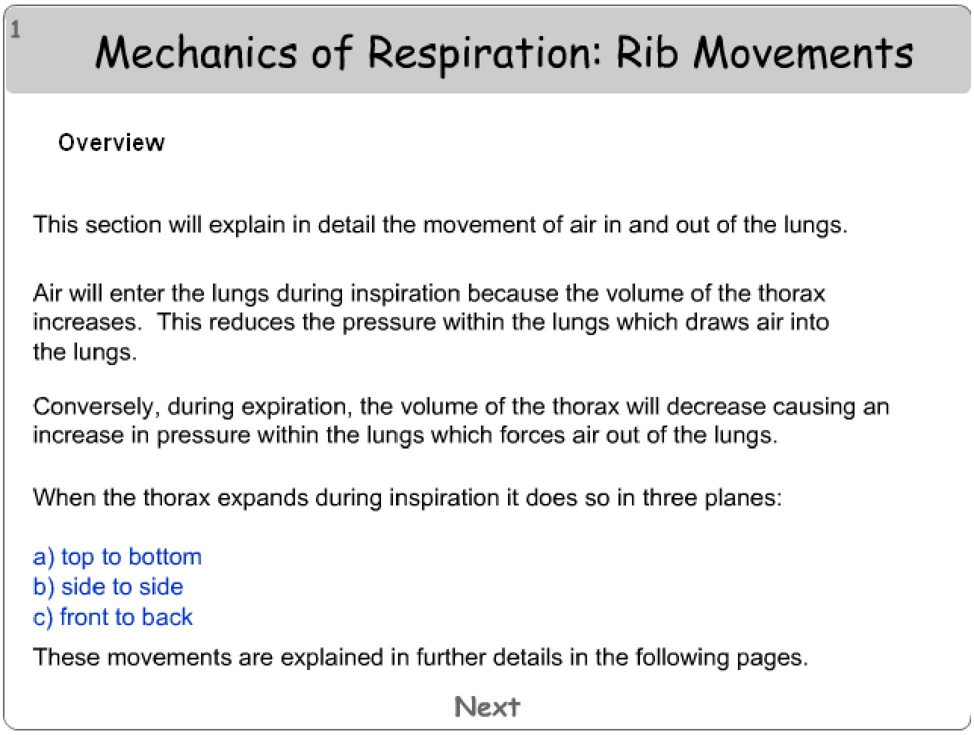
Muscles in Ventilation

Any muscles which can add power to ventilation are called accessory muscles of respiration. During inspiration it is largely pectoralis major and sternomastoid which do this. During expiration it is the abdominal wall muscles and latissimus dorsi. Respiratory patients will often brace themselves into a position which makes these muscles most efficient and aids ventilation.

With increased effort of breathing, not only does the diaphragm flatten, but its central tendon descends towards the abdomen. The descent is limited by its attachment to the pericardium above and the abdominal viscera below. In some cases (such as pregnancy or ascites) the diaphragm cannot descend properly as the abdominal cavity is pressing upwards. This is what we call 'splinting of the diaphragm'.

Overview of Rib Movements

Work through this interactive sequence - click on the words in different colours to bring up pop-ups and initiate the animation.



Overview of Mechanics of Respiration

Work through this interactive sequence which gives an oveview of the mechanics of respiration. Click on the text highlighted in red to reveal pop-up information and animations.

1

Mechanics of Respiration: Pressure Changes

During quiet breathing inspiration is active and expiration is largely passive.

The mechanical changes which occur during inspiration in the structure of the thorax and the lungs enable us to explain quiet breathing in terms of pressure changes between the internal environment and the external atmosphere. These pressure changes are generated actively by muscle contraction and passively by chest wall recoil.

The special properties of the pleural space allow pressure changes in the chest cage to be transmitted to the lungs. Opposing forces such as chest and lung elastic recoil and airway restistance must be overcome in both the chest cage and the lungs.

To fully understand the mechanics of recoil of the chest and lungs and the generation of pressures within the pleura and alveoli one must examine the relationship that exists between pressure and volume.

This unit will explain these relationships and also consider the work of breathing.

Chapter: Gas Exchange

Dalton's Law

The 'pressure' of a gas is the force exerted by the weight of the molecules within it. For a mixture of gases, the total pressure exerted is the sum of the pressures that each gas would exert if it were alone, i.e.

p = p1 + p2 + p3 + ...

where p is the total or measured pressure and p1, p2, ... are the partial pressures of the individual gases.

Partial Pressure of Air

For air, an appropriate form of Dalton's law would be:

p(air) = p(N2) + p(O2) + p(CO2) + ...

At room temperature, the partial pressures of each of the components are directly proportional to the number of moles of that component in any volume of air.

When the total pressure of air is 100 kPa (one bar), the partial pressures of each of its components (in kPa) are numerically equal to the molar percent.

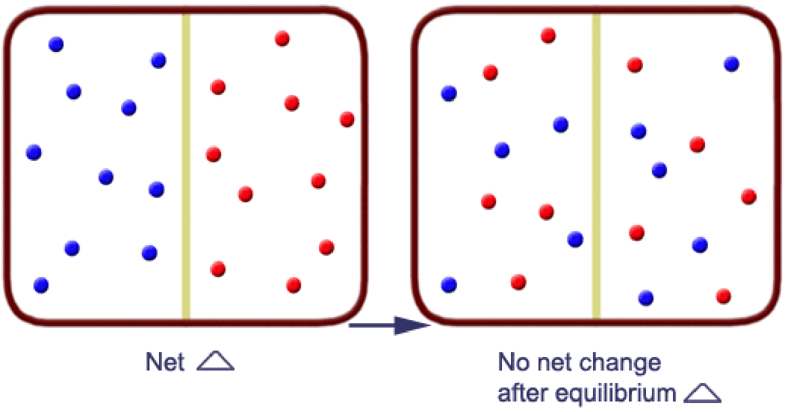
So, the partial pressures of the major components of dry air at 100 kPa:

Nitrogen 78 kPa
Oxygen 21 kPa
Carbon dioxide 0.03 kPa etc.

Diffusion

Diffusion occurs when there is a difference in partial pressures (concentrations) across a semi-permeable membrane. Gases move from an area of high pressure to an area of lower pressure until equilibrium is achieved.

This process depends on the thickness and surface area of the semi-permeable membrane. It is a constant process.



Breathing is a cycle of inspiration and expiration to circulate gases in and out of the alveoli (though in reality very little alveolar gas is exchanged each cycle). However, the process of gas exchange at the respiratory membrane is diffusion dependant and is therefore constant, not cyclical with breathing.

Partial Pressures of Alveolar Air

Alveolar air is different from atmospheric air. It is in equilibrium with blood in the capillaries.

Multiple Choice Question: How will partial pressure in alveoli be different from normal air?

Possible answers:

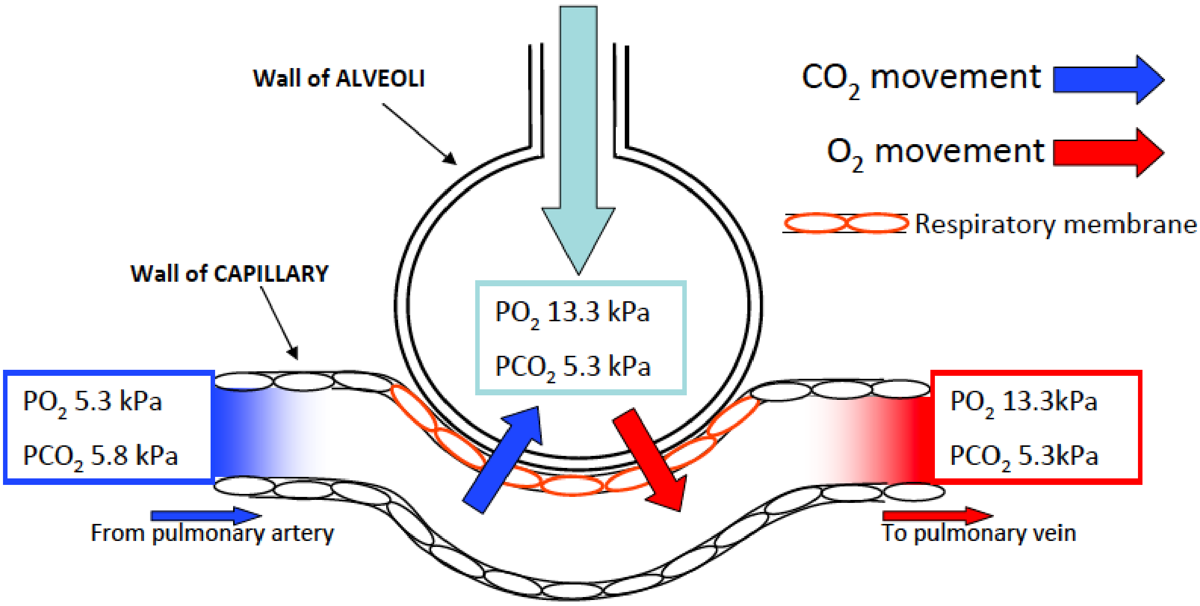
1. More CO2, less O2, more H20

2. More CO2, more O2, more H2O

3. Less CO2, less O2, more H2O

4. Less CO2, more O2, more H2O

Alveolar Air



Cellular metabolism uses oxygen and creates carbon dioxide as a by-product. Blood arriving at the lungs has come from the tissues of the body and therefore contains high levels of CO2 and low levels of O2. Gases exchange across the respiratory membrane down their pressure gradients so that carbon dioxide is off-loaded and oxygen in the blood increases.

During ventilation only a small fraction of the alveolar gases are exchanged with each breath (breath to breath alveolar pO2 only changes up to about 3mmHg and therefore can be considered relatively constant). As diffusion is constant, the composition of alveolar air is relatively constant. Diffusion continues until equilibrium is reached (i.e. alveolar partial pressures=capillary partial pressures). Flow through the capillary beds is slow to allow this diffusion time to occur.

Partial pressures of gases						
	Alveolar air		Deoxygenated blood		Oxygenated blood	
Gas	kPA	mmHg	kPA	mmHg	kPA	mmHg
Oxygen	13.3	100	5.3	40	13.3	100
Carbon Dioxide	5.3	40	5.8	44	5.3	40
Nitrogen (&inert gases)	76.4	573	76.4	573	76.4	573
Water Vapour	6.3/101.3	47/760				

Ventilation-Perfusion Relationships - V/Q Matching

Transfer of gases between the blood and the atmosphere is dependent on:

Ventilation (V): the rate at which gas is passing through the lungs.
Perfusion (Q): the rate at which blood is passing through the lung.

Ventilation and perfusion vary in different areas of the lung (see later), but if they were completely uniform for all alveoli, the

typical overall values for the lung would be:

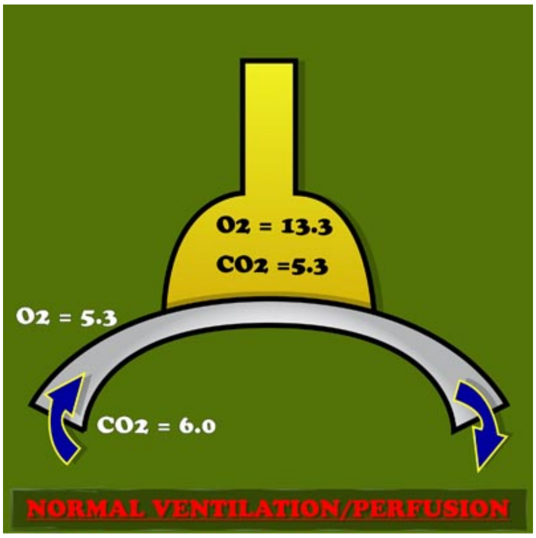


Image caption: 4 l/min for alveolar ventilation (V)
5 l/min for pulmonary blood flow or perfusion (Q)
This would mean the overall ratio of ventilation to perfusion (V/Q) would be 4/5 or 0.8.

In healthy adults, most alveoli have a V/Q ratio between 0.5 and 2.0. Gas exchange can easily take place within this range so that the blood leaving the capillaries has pO2 and pCO2 values close to those within the alveoli.

V/Q Mismatch

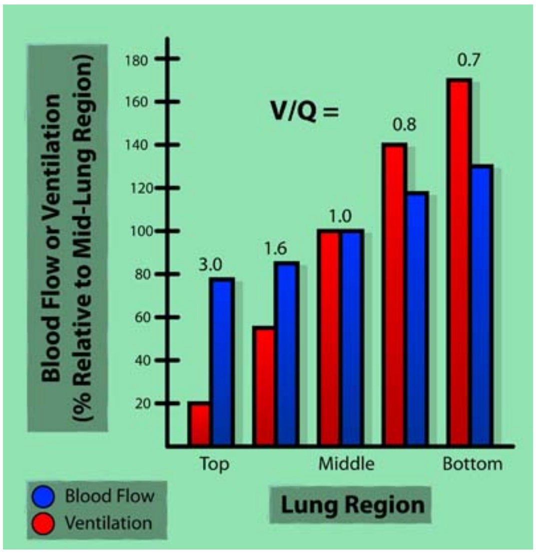


Image caption: Ventilation and perfusion varies throughout the lung as shown in the graph, and also in different disease states.

The lung bases have more perfusion than the top of the lungs. The upper lobes are relatively more ventilated.

Low V/Q Ratio

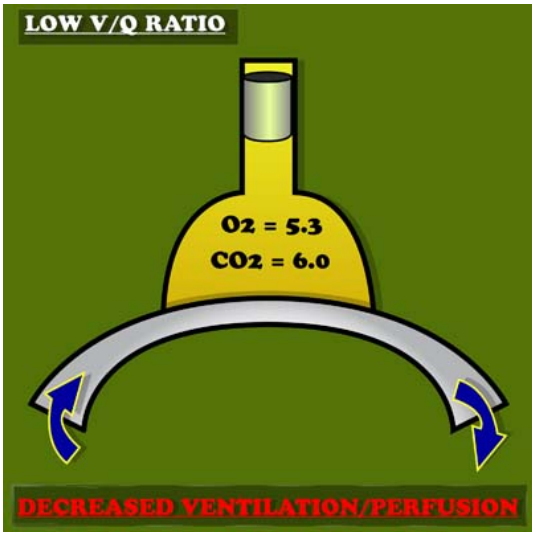


Image caption: If alveoli have NO ventilation but good perfusion, the V/Q is zero (0/Q=0). Blood flowing through this area is not exposed to alveolar gas, so its pO2 and pCO2 remain the same as venous blood - it as is if this blood has bypassed or 'shunted' past the lungs.

This is referred to as physiological shunt (an anatomical shunt occurs if venous blood can bypass the lungs to reach the arterial blood supply and dilute it with deoxygneated blood as happens in cyanotic heat disease).

High V/Q Ratio

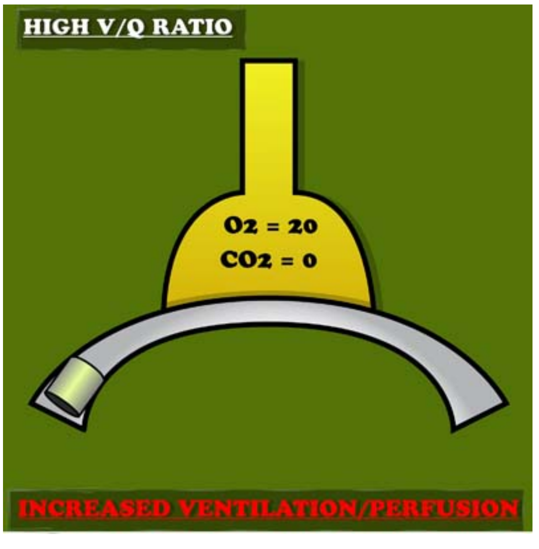


Image caption: If the alveoli have no perfusion but normal ventilation, the V/Q is very high (V/0). Blood is not exposed to these alveoli, so diffusion cannot take place. Alveolar gas will have the same composition as saturated inspired air (approx pO2=20, pCO2=0).

These areas are alveolar dead space.

Dead Space

Dead space is the volume of inspired gas in a breath which does not take part in gas exchange.

- Anatomical dead space is the volume of the conducting airways (approx 150ml).
- Alveolar dead space is the volume of poorly perfused alveoli (high V/Q). In health, this is very small.

- Physiological dead space is the sum of the two.

Excess dead space causes a tendency to hypercapnia because areas with high V/Q are poor at off-loading CO2. In reality this rise in CO2 is sensed by the brain and compensated for by increasing the alveolar ventilation rate (hyperventilation). As it requires extra energy it is sometimes referred to as wasted ventilation.

Overall Effects of Regional v/Q Mismatch

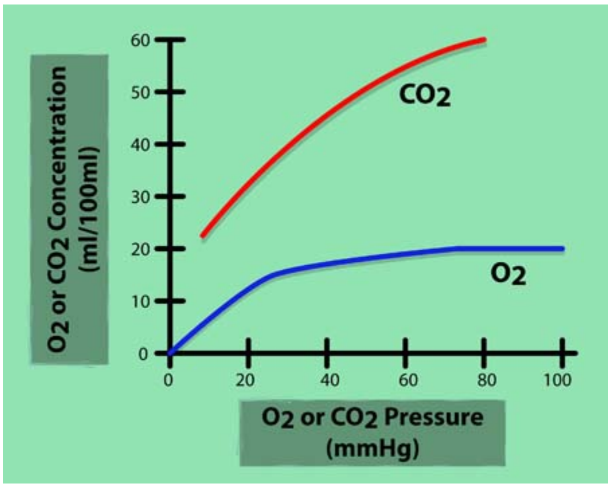
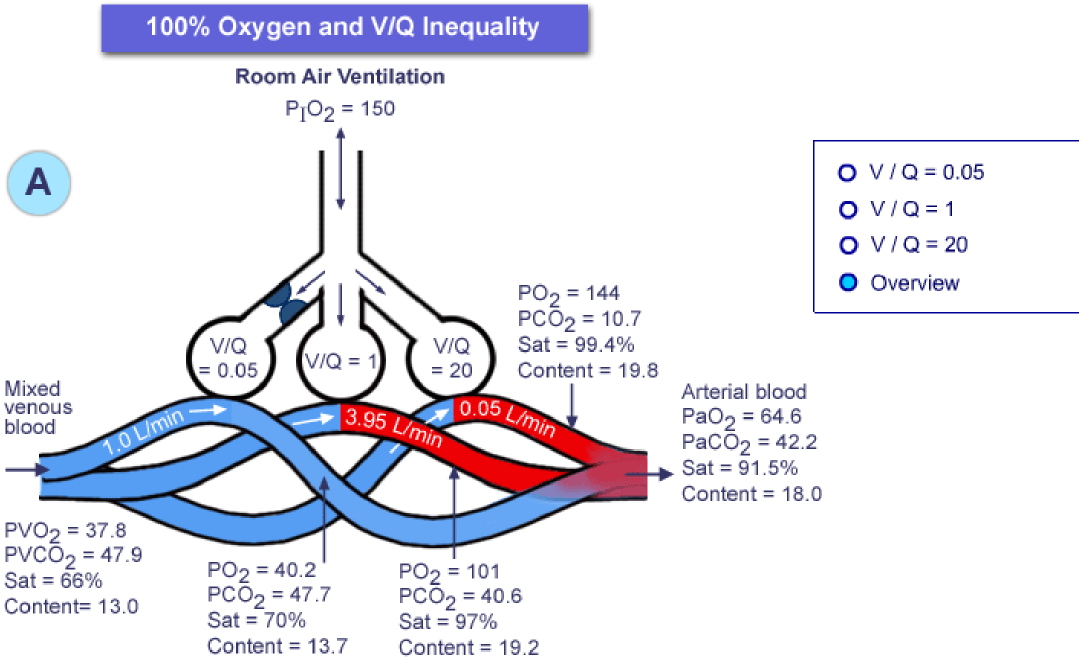


Image caption: The dissociation curves for CO2 and O2 are quite different as shown in this graph.

Now take a look at the animation below. This shows 3 theoretical lung units, low V/Q (left), normal (centre) and high V/Q (right). Look at the change in concentration of oxygen and carbon dioxide at each lung unit (click the options on the right) and then click the overview to see the overall result.

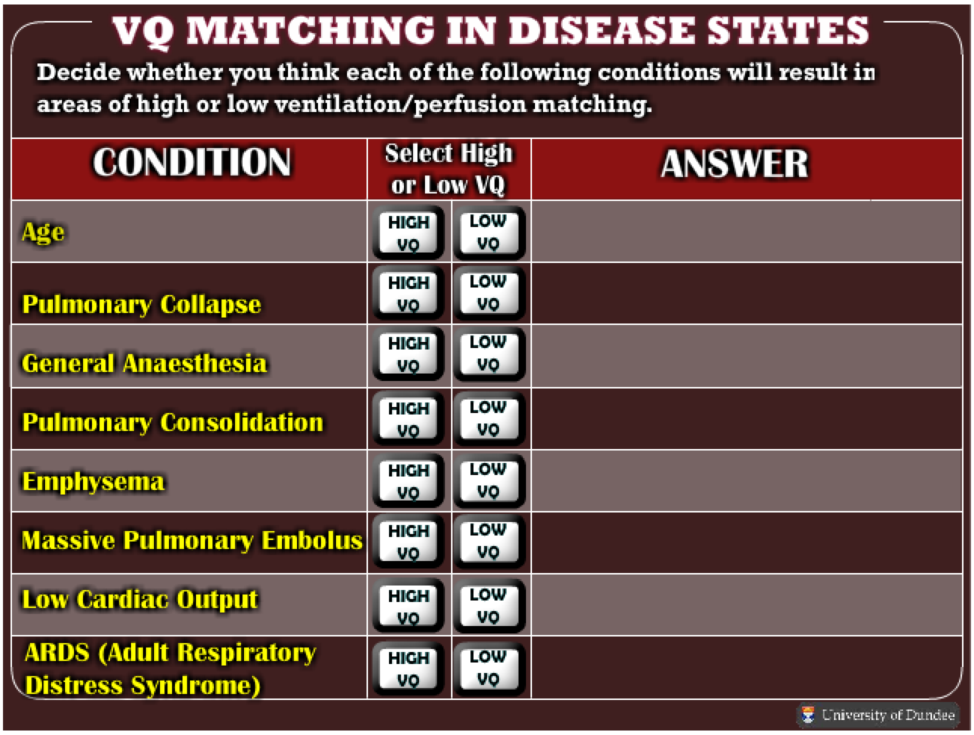
Hypoxia from the low V/Q area has a greater effect on the final pO2 of the arterial blood. The pO2 from the high V/Q area will be on the flat part of the dissociation curve so that the overall concentration (or saturation) is not as greatly effected.

Increased ventilation rate will raise CO2 output from lung units with both high and low V/Q ratios, whereas the flat O2 dissociation curve means that only units with low V/Q ratios will benefit increase O2 i.e. increasing the ventilation rate is more effective at changing CO2 than O2.



V/Q Matching in Disease States

Teacher's Comment: **Decide whether you think each of the following conditions will result in areas of high or low ventilation/perfusion.**



VQ MATCHING IN DISEASE STATES

Decide whether you think each of the following conditions will result in areas of high or low ventilation/perfusion matching.

CONDITION	Select High or Low VQ		ANSWER
Age	HIGH VQ	LOW VQ	
Pulmonary Collapse	HIGH VQ	LOW VQ	
General Anaesthesia	HIGH VQ	LOW VQ	
Pulmonary Consolidation	HIGH VQ	LOW VQ	
Emphysema	HIGH VQ	LOW VQ	
Massive Pulmonary Embolus	HIGH VQ	LOW VQ	
Low Cardiac Output	HIGH VQ	LOW VQ	
ARDS (Adult Respiratory Distress Syndrome)	HIGH VQ	LOW VQ	

University of Dundee