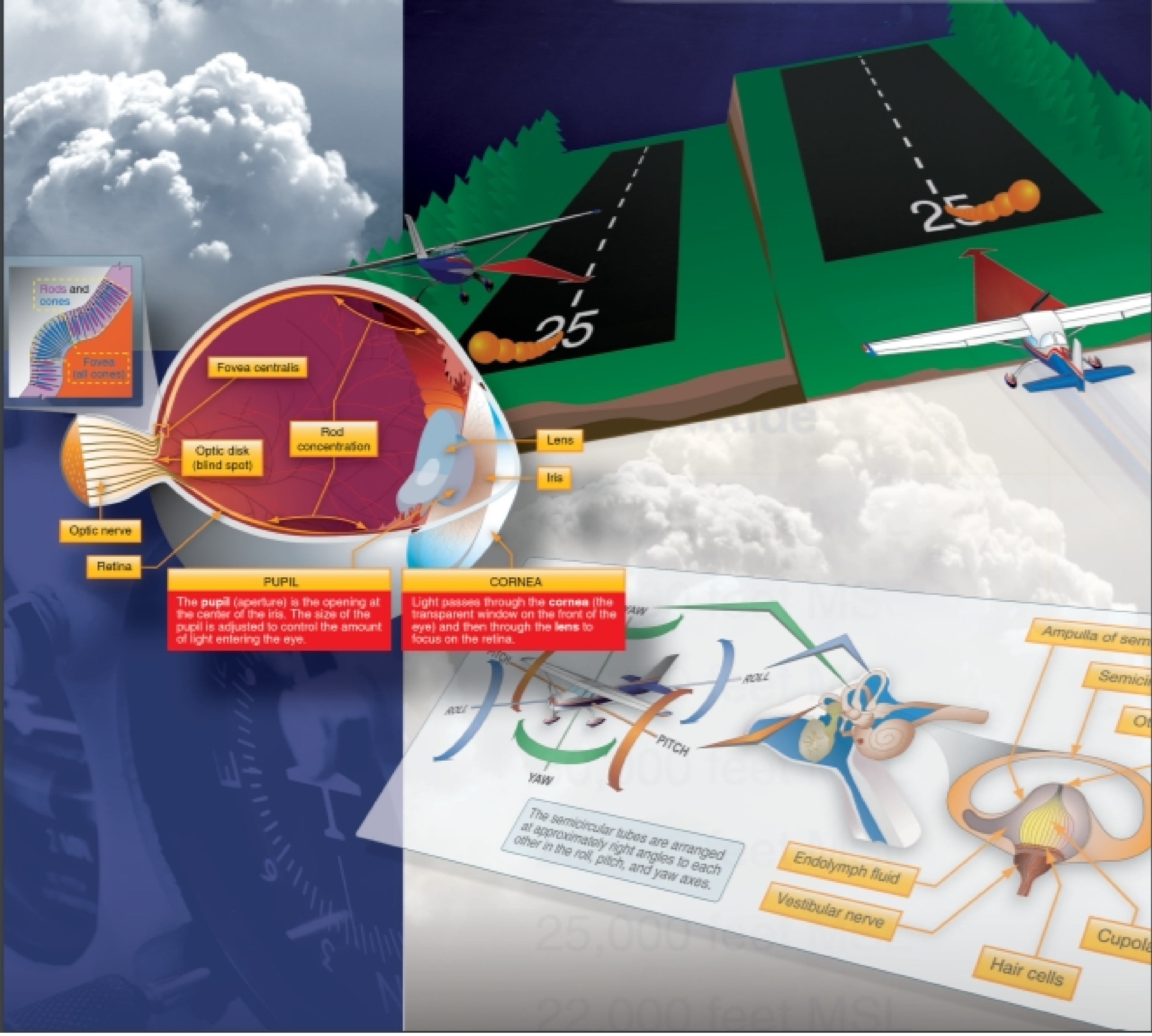
Aeromedical Factors

Introduction

It is important for a pilot to be aware of the mental and physical standards required for the type of flying performed. This chapter provides information on medical certification and on a variety of aeromedical factors related to flight activities.



PPL 6: HUMAN PERFORMANCE AND LIMITATIONS

Human Factors - The study of how people interact with their environments. In the case of general aviation, it is the study of how pilot performance is influenced by such issues as the design of cockpits, the function of the organs of the body, the effects of emotions, and the interaction and communication with the other participants of the aviation community, such as other crew members and air traffic control personnel.

More than 70% of all aircraft accidents in general aviation are caused by human error. As far as recreational pilots are concerned, the word "human" could be replaced by "pilot". Flying is great fun, but like any endeavour, the less we practice, the worse we become at it. It usually the actions and decisions of the pilot that cause the problem. Technology is leaving us far, far behind, and the blame is very rarely attributed to aircraft system failures.

We learn all we need to know about aircraft technology, yet we overlook the main contributor to accidents - the human being. If we understand, very basically, just how far we can push this 80-odd kilogram pile of flesh and bones, we will have taken a giant step forward in understanding where to draw the line between risk and safety.

PPL 6: HUMAN PERFORMANCE AND LIMITATIONS

The Atmosphere

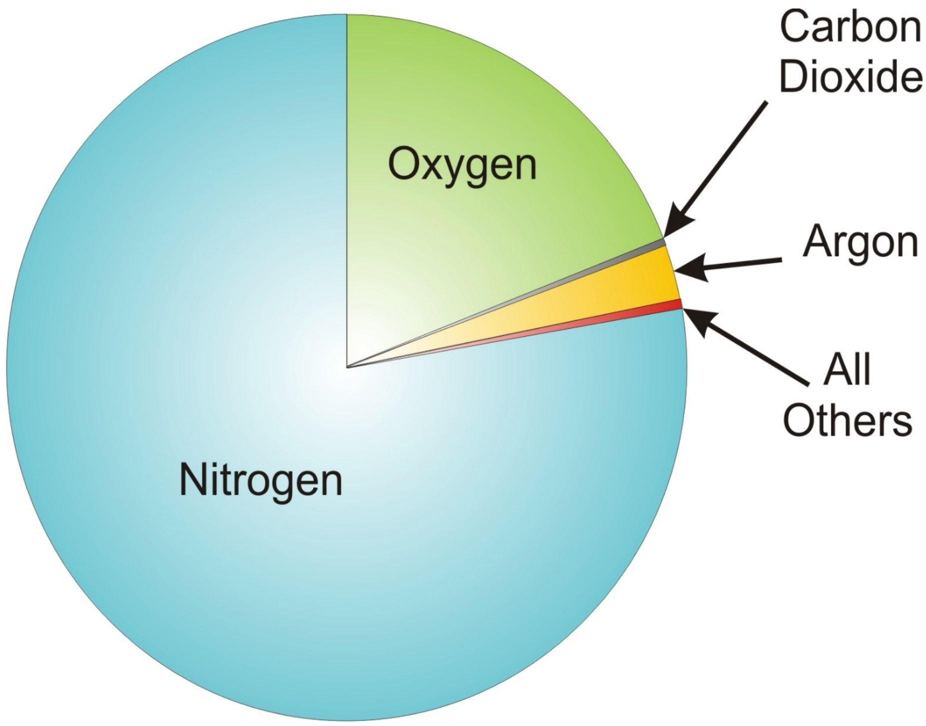


Figure 6.1

Composition of the Atmosphere

In Chapters 1 (Principles of Flight) and 4 (Meteorology) we noted the composition of the atmosphere. The Earth's atmosphere (or air) is a layer of gases surrounding the planet that is retained by the Earth's gravity. Dry air contains roughly (by volume) 78.08% nitrogen, 20.95% oxygen, 0.93% argon, 0.038% carbon dioxide, and trace amounts of other gases (Figure 6.1). Air also contains a variable amount of water vapour, on average around 1%. The atmosphere protects life on Earth by absorbing ultraviolet solar radiation, warming the surface through heat retention (greenhouse effect), and reducing temperature extremes between day and night.

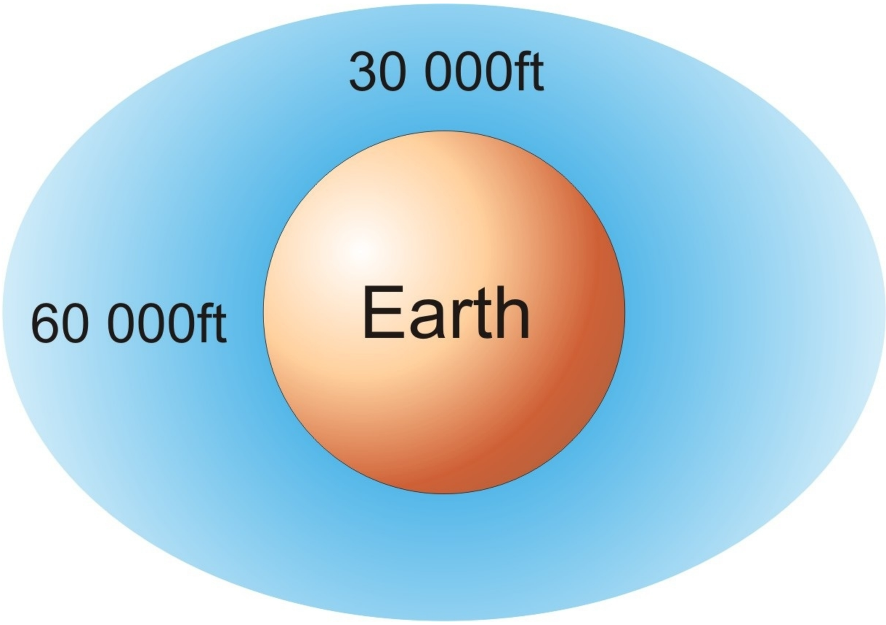


Figure 6.2

The Atmosphere

The lowest level of the atmosphere is the troposphere. The composition of the air in the troposphere remains constant, and the troposphere covers the earth up to about 30 000ft at the poles, and 60 000ft at the equator (Figure 6.2). The boundary of the troposphere is known as the tropopause.

In the troposphere there is normally a decline of temperature with increase in altitude. Pressure also decreases with altitude. Cold temperatures will increase air density, while low pressures will decrease density. Pressure will always decrease with an increase in altitude, but in the real world temperature does not necessarily decreases as ISA would have us believe, and temperature can even increase (inversion), stay the same (isothermal layer), or decrease at varying rates. Pressure will always be the dominant force, so density will also decrease with increase in altitude. The change of pressure in the atmosphere will depend on height, and small changes in height at low altitude will result in a much greater change in pressure than the same height change at high altitude.

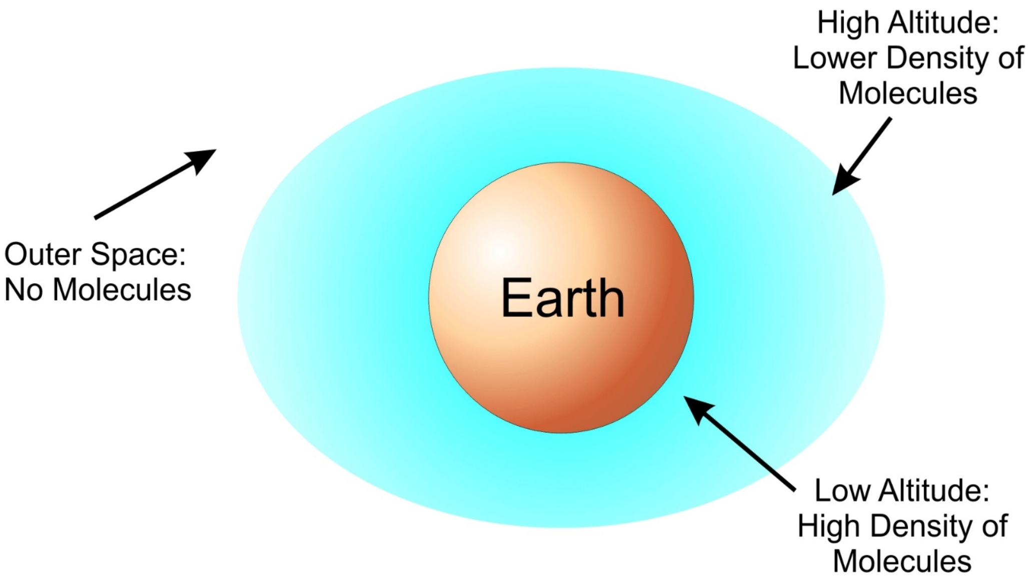


Figure 6.3

Pressure in the Atmosphere

Oxygen Requirement of Tissues

It is the oxygen that we are primarily concerned about, because without oxygen, we cannot survive. In order to keep going, our tissues and cells need energy, and this is provided by a process of energy generation and use called metabolism. Oxygen combines with nutrients in the body to produce the energy required for day to day living, as well as the by-products of water (H_2O) and carbon dioxide (CO_2).

Metabolism is a constant process that begins when we are conceived and ends when we die. It is a vital process for all life forms - not just humans. If metabolism stops, a living thing dies.

Here's an example of how the process of metabolism works in humans - and it begins with plants: First, a green plant takes in energy from sunlight. The plant uses this energy and the molecule chlorophyll (which gives plants their green colour) to build sugars from water and carbon dioxide in a process known as photosynthesis.

When people and animals eat the plants (or, if they're carnivores, when they eat animals that have eaten the plants), they take in this energy (in the form of sugar), along with other vital cell-building chemicals. The body's next step is to break the sugar down so that the energy released can be distributed to, and used as fuel by, the body's cells.

After food is eaten, molecules in the digestive system called enzymes break proteins down into amino acids, fats into fatty acids, and carbohydrates into simple sugars (e.g., glucose). In addition to sugar, both amino acids and fatty acids can be used as energy sources by the body when needed. These compounds are absorbed into the blood, which transports them to the cells.

After they enter the cells, other enzymes act to speed up or regulate the chemical reactions involved with "metabolising" these compounds. During these processes, the energy from these compounds can be released for use by the body or stored in body tissues, especially the liver, muscles, and body fat.

In this way, the process of metabolism is really a balancing act involving two kinds of activities that go on at the same time - the building up of body tissues and energy stores and the breaking down of body tissues and energy stores to generate more fuel for body functions.

a. Anabolism, or constructive metabolism, is all about building and storing: It supports the growth of new cells, the maintenance of body tissues, and the storage of energy for use in the future. During anabolism, small molecules are changed into larger, more complex molecules of carbohydrate, protein, and fat.

b. Catabolism, or destructive metabolism, is the process that produces the energy required for all activity in the cells. In this process, cells break down large molecules (mostly carbohydrates and fats) to release energy. This energy release provides fuel for anabolism, heats the body, and enables the muscles to contract and the body to move. As complex chemical units are broken down into more simple substances, the waste products released in the process of catabolism are removed from the body through the skin, kidneys, lungs, and intestines.

Several of the hormones of the endocrine system are involved in controlling the rate and direction of metabolism. Thyroxine, a hormone produced and released by the thyroid gland, plays a key role in determining how fast or slow the chemical reactions of metabolism proceed in a person's body.

Another gland, the pancreas secretes hormones that help determine whether the body's main metabolic activity at a particular time will be anabolic or catabolic. For example, after eating a meal, usually more anabolic activity occurs because eating increases the level of glucose - the body's most important fuel - in the blood. The pancreas senses this increased level of glucose and releases the hormone insulin, which signals cells to increase their anabolic activities.

In Chapter 4 (Meteorology) we found that as altitude increases, atmospheric pressure drops, and so does temperature. Both of these reductions have an effect on us as humans.

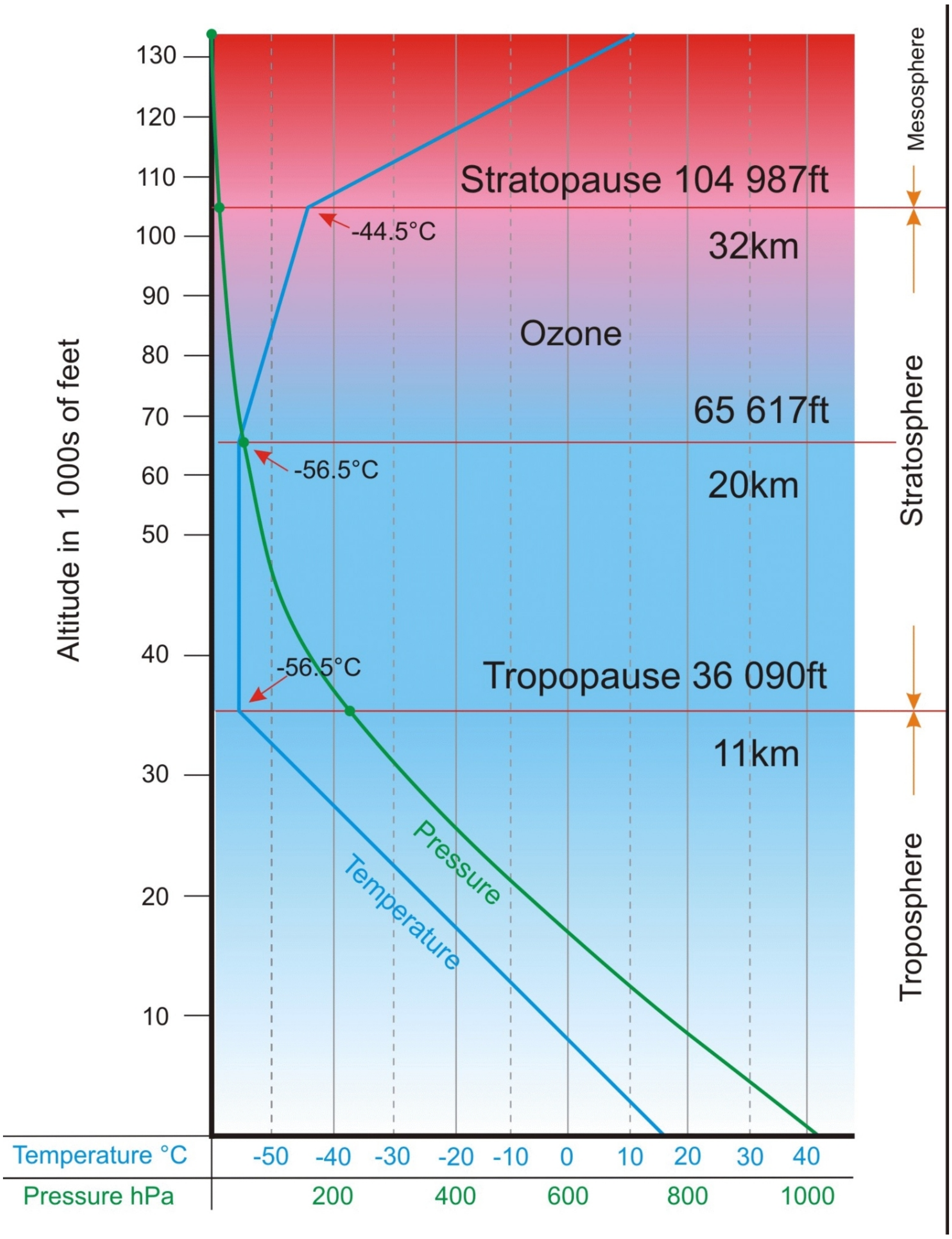


Figure 6.4

Pressure and Temperature in ISA

It is important that one understands both aspects well as they play a very important part in whether we survive at altitude or not. As most of your flying as a recreational pilot will be carried out in the lower regions of the atmosphere (unless you can afford to pay your way on a Russian space flight!), we will concern ourselves with that region only.

The lower region of the atmosphere is called the troposphere. It is characterised by a reduction in temperature of 1,98°C per thousand feet of altitude gained. This drop in temperature continues until the temperature reaches -56,5°C. This is regarded as the minimum temperature that exists within the troposphere. The troposphere itself extends to an altitude of about 26000 feet (8km) at the poles, and 60000 feet (18km) at the equator. This is because the air cools at a rate of 1,98°C/1 000' of altitude gained. As the temperature at the equator is hotter that at the poles, it makes sense that it takes longer to get to the minimum temperature.

Another feature of the troposphere is that as one climbs higher into the troposphere, the weight of the air above you is becoming less and less. This has the effect of reducing the atmospheric pressure and density as one climbs. A significant point to remember is that the air above us is heaviest at sea level, and drops to about half the weight at approximately 18000 feet. This means too, that the pressure at 18000 feet is roughly half of what it is at sea level. Using the Pathfinder, Flight > Altitude > Std Atmos (Standard Atmosphere), you can find the ISA values for pressure and temperature at any altitude.

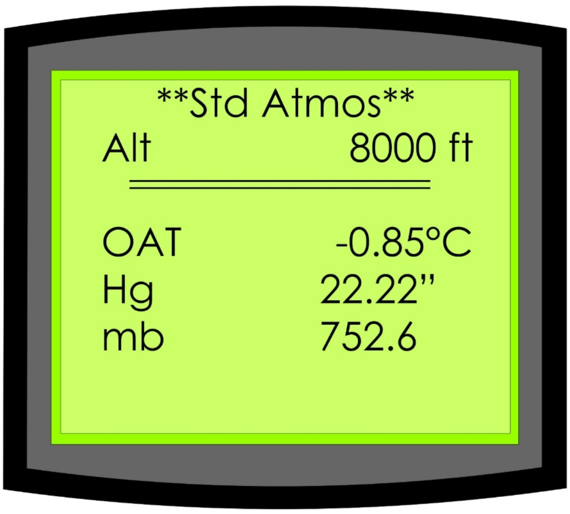


Figure 6.5

ISA conditions at 8000 feet

The Gas Laws

There are a number of gas laws must be understood to appreciate the changes that take place in the body when it is subjected to pressure changes.

BOYLE'S LAW: Boyle's law states that providing the temperature is constant, the volume of a gas is inversely proportional to its pressure. The temperature referred to in the definition is your body temperature and not the air temperature, which according to ISA decreases with increasing altitude. Body temperature will remain constant as you climb, but pressure will reduce.

This applies to expanding gas in the middle ear, sinuses and gastro-intestinal system

21. For the mathematically minded, this can be seen as follows:

$$\frac{P1}{P2} = \frac{V2}{P1}$$

or $PV = k$, where P = pressure, V = volume, and k is a constant.

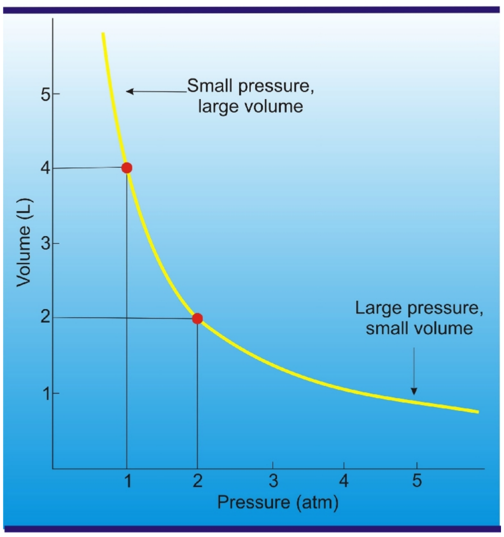


Figure 6.6

Boyle's Law

DALTON'S LAW: Dalton's Law states that the total pressure of a gas mixture is equal to the sum of its partial pressures.

This means that the proportion of oxygen remains 21% throughout the atmosphere, irrespective of the total atmospheric pressure at that altitude.

This is a problem for us.

This plays a major role in Hypoxia. If the total pressure of the atmosphere drops, then the partial pressure of the oxygen will drop accordingly. Once it reaches a value which is too low, we cannot survive. More of this in Hypoxia.

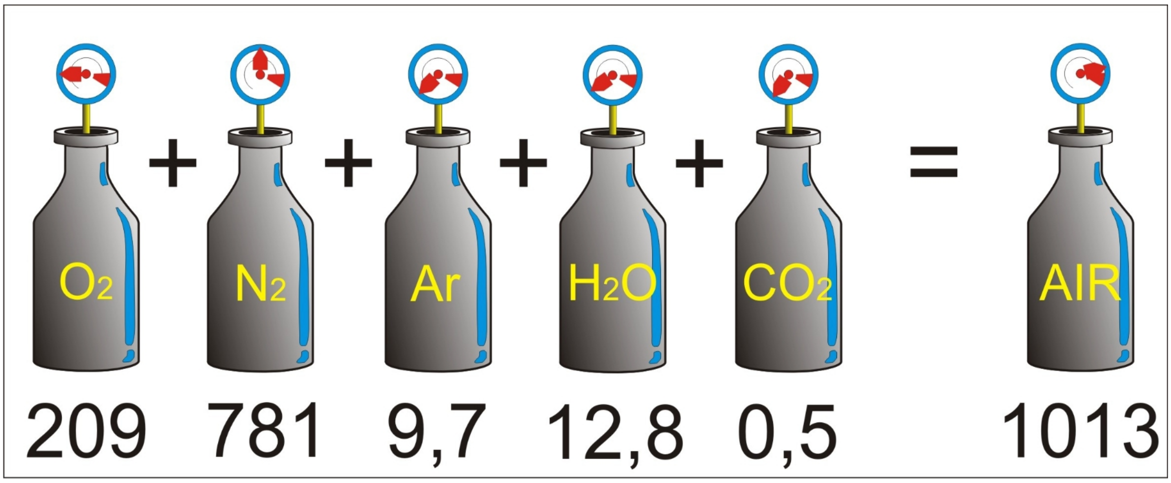


Figure 6.7

Dalton's Law of Partial Pressures

HENRY'S LAW: Henry's Law states that at equilibrium the amount of gas dissolved in a liquid is proportional to the gas pressure. The gas in question is nitrogen, which makes up about 78% of atmospheric air.

By the same token, that gas will come out of solution if the gas pressure reduces. This applies to decompression sickness, when the gas comes out of solution too quickly.

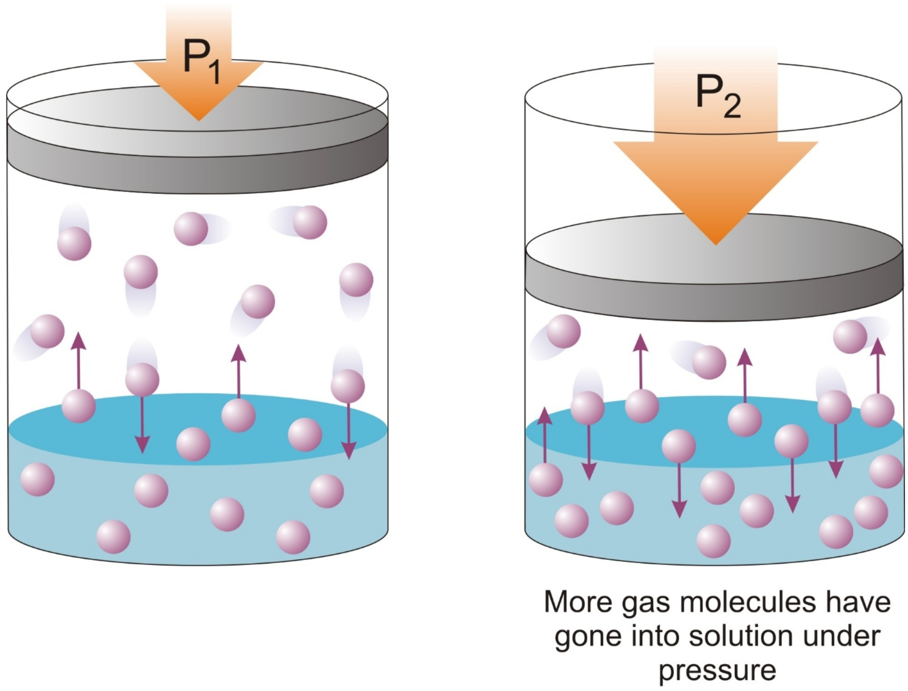


Figure 6.8

Henry's Law

FICK'S LAW: Fick's Law states that the net diffusion rate of a gas across a membrane is proportional to the difference in partial pressure on the two sides, proportional to the area of the membrane and inversely proportional to the thickness of the membrane.

Gas exchange or respiration takes place at a respiratory surface - the boundary between the external environment and the interior of the body. The respiratory surface is governed by Fick's law, which determines that respiratory surfaces must have:

- a large surface area
- a thin permeable surface
- a moist exchange surface.

This applies to what is known as part of the internal respiration process. Gas, in this case oxygen, can pass through the respiratory surface, or membrane, in this case the alveolar wall, into the blood in the capillaries. For this to happen there must be a pressure differential between the two sides of the membrane. The alveolar walls, if opened out, will cover an area of about 100m^2, or roughly the size of a tennis court for each lung, giving a large surface area. The larger the area, the more the gas that can pass through. The membrane is about one millionth of a metre in thickness, which together with the large area, makes for a very effective gas exchange. The membrane will be affected by tobacco smoke, resulting in a build-up of tar in the alveolar, thus thickening the membrane and reducing the rate of diffusion across the membrane.

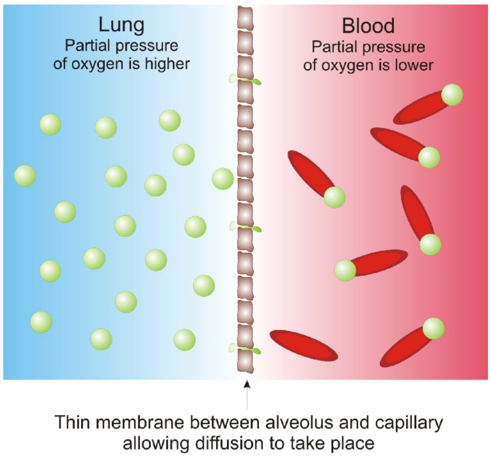


Figure 6.9

Diffusion between lung and capillary

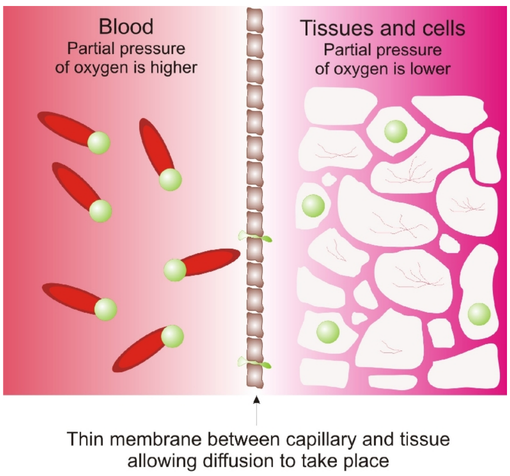


Figure 6.10

Diffusion between capillary and tissue

CHARLES'S LAW: Charles's Law states that the volume of a fixed mass of gas held at a constant pressure varies directly with absolute temperature.

This has little to do with aviation, and relates to the expansion based on a temperature increase.

GENERAL GAS LAW: If we combine Boyle's Law and Charles's Law we end up with the General Gas Law.

This law applies to "ideal" gases where the molecules are assumed to be perfectly elastic. For practical purposes, we can assume that the law applies to all gases.

For the mathematically minded, this can be seen as follows:

$$\frac{PV}{T} = k$$

where P = pressure,
V = volume,
T = temperature (°A) and
k is a constant.

If any of the three variables P,V or T changes, at least one of the others must change to maintain the balance.

The Heart

Your heart is a muscular organ that acts like a pump to send blood throughout your body all the time. Your heart is at the centre of your circulatory system, which delivers blood to all areas of your body. An electrical system regulates the heart and uses electrical signals to contract the heart's walls. When the walls contract, blood is pumped into your circulatory system.

Your circulatory system is made up of a network of blood vessels, such as arteries, veins, and capillaries. The vessels in this network carry blood to and from all areas of your body. A system of inlet and outlet valves in your heart's chambers works to ensure that blood flows in the right direction.

Your heart is vital to your health and nearly everything that goes on in your body. Without the heart's pumping action, blood cannot circulate within your body.

Your blood carries the oxygen and nutrients that your organs need to function normally. Blood also carries carbon dioxide, a waste product, to your lungs to be passed out of your body and into the air. A healthy heart supplies the areas of your body with the right amount of blood at the right rate needed to function normally. If disease or injury weakens your heart, your body's organs won't receive enough blood to function normally.

Anatomy of the Heart

Your heart is located under the ribcage in the centre of your chest between your right and left lung. It's shaped like an upside-down pear. Its muscular walls beat, or contract, pumping blood continuously to all parts of your body.

The size of your heart can vary depending on your age, size, or the condition of your heart. A normal, healthy, adult heart most often is the size of an average clenched adult fist. Some diseases of the heart can cause it to become larger.

The Exterior of the Heart

Figure 6.11 shows the front surface of the heart, including the coronary arteries and major blood vessels. The heart has four chambers. The right and left atria and the right and left ventricles. In Figure 6.11 the blue indicates Oxygen-poor blood, while red indicates oxygen rich blood.

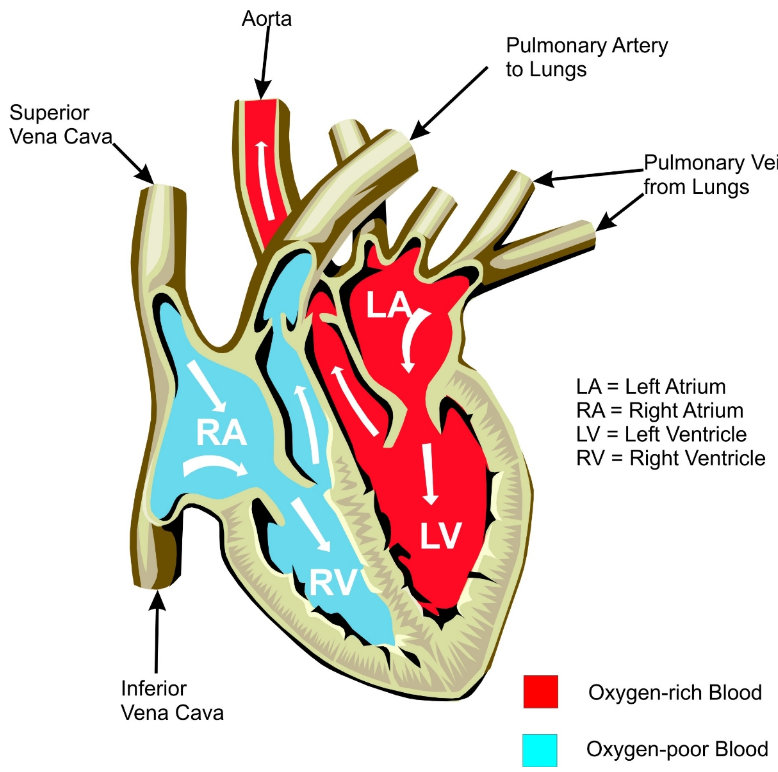


Figure 6.11

The Heart

Connected to the heart are some of the main blood vessel's arteries and veins that make up your blood circulatory system.

The ventricle on the right side of your heart pumps blood from the heart to your lungs. When you breathe air in, oxygen passes from your lungs through blood vessels where it's added to your blood. Carbon dioxide, a waste product, is passed from your blood through blood vessels to your lungs and is removed from your body when you breathe air out.

The atrium on the left side of your heart receives oxygen-rich blood from the lungs. The pumping action of your left ventricle sends this oxygen-rich blood through the aorta (a main artery) to the rest of your body.

The Right Side of Your Heart

The superior and inferior vena cavae are in blue to the left of the muscle as you look at Figure 6.11. These veins are the largest veins in your body. They carry used (oxygen-poor) blood to the right atrium of your heart. Used blood has had its oxygen removed and used by your body's organs and tissues. The superior vena cava carries used blood from the upper parts of your body, including your head, chest, arms, and neck. The inferior vena cava carries used blood from the lower parts of your body.

The used blood from the vena cavae flows into your heart's right atrium and then on to the right ventricle. From the right ventricle, the used blood is pumped through the pulmonary arteries (in blue in the centre of Figure 6.11) to your lungs. Here, through many small, thin blood vessels called capillaries, your blood picks up oxygen needed by all the areas of your body.

The oxygen-rich blood passes from your lungs back to your heart through the pulmonary veins (in red to the right of the left atrium in Figure 6.11).

The Left Side of Your Heart

Oxygen-rich blood from your lungs passes through the pulmonary veins into the left atrium and is then pumped into the left ventricle. From the left ventricle, your blood is pumped to the rest of your body through the aorta, the major artery.

Like all of your organs, your heart needs blood rich with oxygen. This oxygen is supplied through the coronary arteries as it's pumped out of your heart's left ventricle. Your coronary arteries are located on your heart's surface at the beginning of the aorta. Your coronary arteries (shown in Figure 6.12) carry oxygen-rich blood to all parts of your heart.

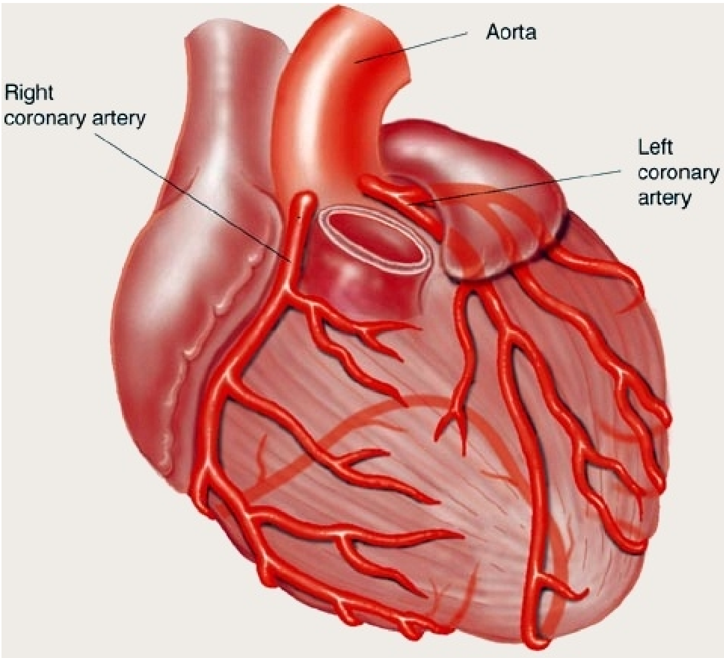


Figure 6.12

Coronary arteries

Heartbeat

Almost everyone has heard the real or recorded sound of a heartbeat. When your heart beats, it makes a “lub-DUB” sound. Between the time you hear “lub” and “DUB” blood is pumped through your heart and circulatory system.

A heartbeat may seem like a simple event repeated over and over. A heartbeat actually is a complicated series of very precise and coordinated events that take place inside and around your heart. Each side of your heart uses an inlet valve to help move blood between the atrium and ventricle. The tricuspid valve does this between the right atrium and ventricle. The mitral valve does this between the left atrium and ventricle. The “lub” is the sound of the mitral and tricuspid valves closing.

Each of your heart’s ventricles has an outlet valve. The right ventricle uses the pulmonary valve to help move blood into the pulmonary arteries. The left ventricle uses the aortic valve to do the same for the aorta. The “DUB” is the sound of the aortic and tricuspid valves closing.

Each heartbeat has two basic parts: diastole (or relaxation, Figure 6.13) and atrial and ventricular systole (or contraction, Figure 6.14). During diastole, the atria and ventricles of your heart relax and begin to fill with blood. At the end of diastole, your heart's atria contract (an event called atrial systole) and pump blood into the ventricles. The atria then begin to relax. Next, your heart's ventricles contract (an event called ventricular systole) and pump blood out of your heart.

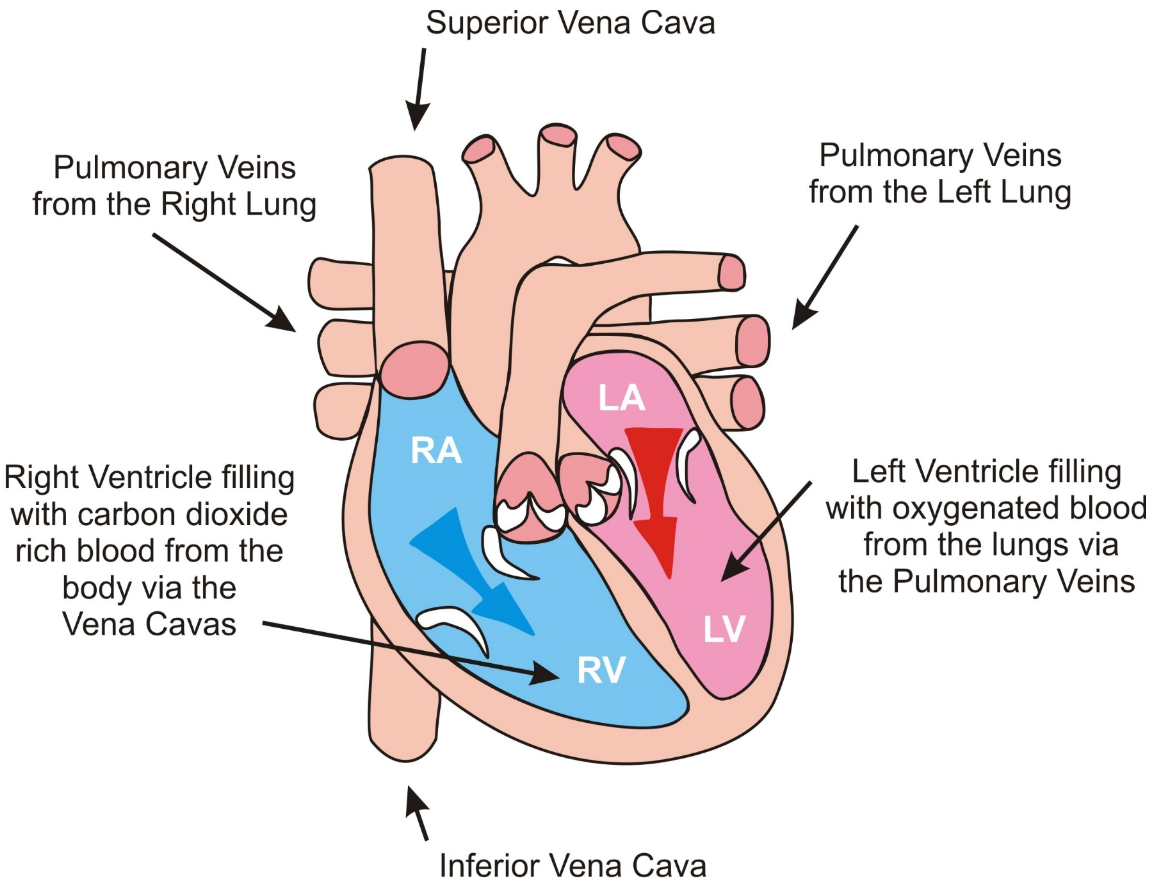


Figure 6.13

Diastole

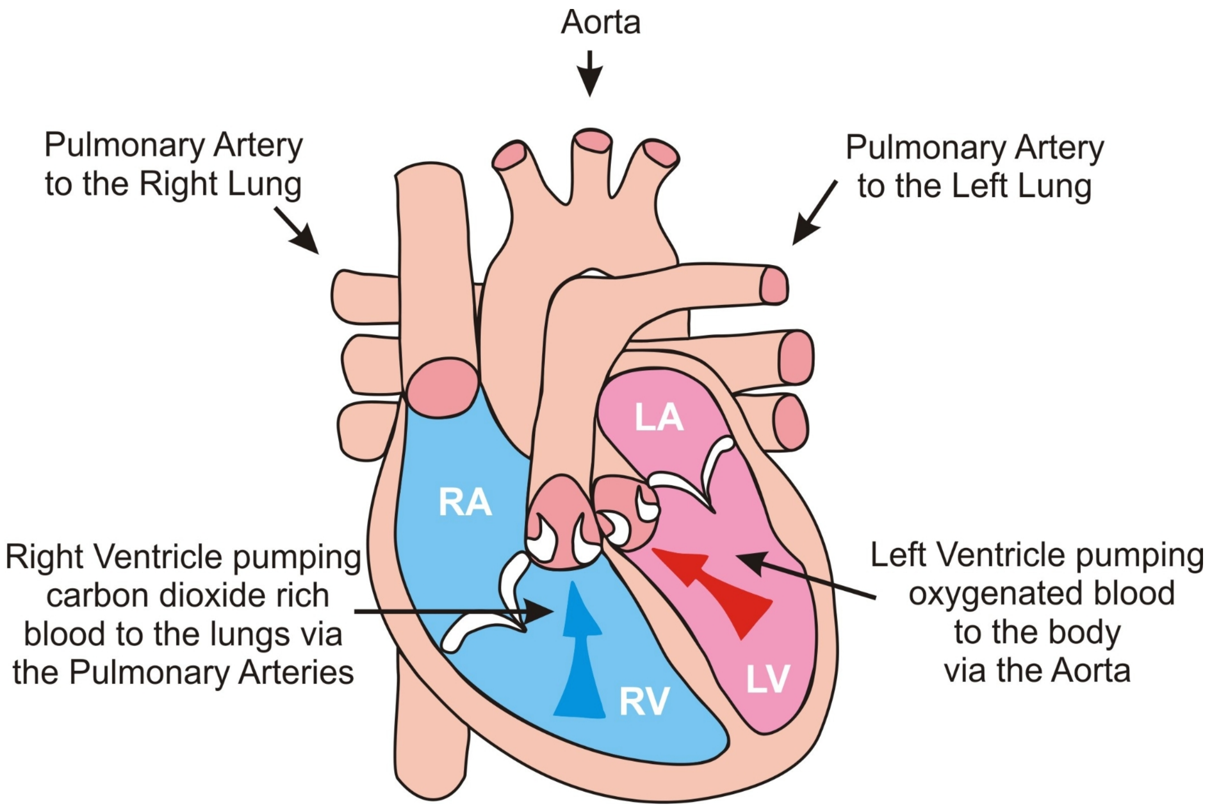


Figure 6.14

Systole

Pumping Action

Your heart uses the four valves to ensure your blood flows only in one direction. Healthy valves open and close in coordination with the pumping action of your heart's atria and ventricles. Each valve has a set of flaps called leaflets or cusps. These seal or open the valves. This allows pumped blood to pass through the chambers and into your blood vessels without backing up or flowing backward.

Blood without oxygen from the two vena cavae fill your heart's right atrium. The atrium contracts (atrial systole). The tricuspid valve located between the right atrium and ventricle opens for a short time and then shuts. This allows blood to enter into the right ventricle without flowing back into the right atrium.

When your heart’s right ventricle fills with blood, it contracts (ventricular systole). The pulmonary valve located between your right ventricle and pulmonary artery opens and closes quickly. This allows blood to enter into your pulmonary artery without flowing back into the right ventricle. This is important because the right ventricle begins to refill with more blood through the tricuspid valve. Blood travels through the pulmonary arteries to your lungs to pick up oxygen.

Oxygen-rich blood returns from the lungs to your heart’s left atrium through the pulmonary veins. As your heart’s left atrium fills with blood, it contracts. This event also is called atrial systole. The mitral valve located between the left atrium and left ventricle opens and closes quickly. This allows blood to pass from the left atrium into the left ventricle without flowing back into the left atrium.

As the left ventricle fills with blood, it contracts. This event also is called ventricular systole. The aortic valve located between the left ventricle and aorta opens and closes quickly. This allows blood to flow into the aorta. The aorta is the main artery that carries blood from your heart to the rest of your body. The aortic valve closes quickly to prevent blood from flowing back into the left ventricle, which is already filling up with new blood.

Circulation and Blood Vessels

Your heart and blood vessels make up your overall blood circulatory system. Your overall blood circulatory system is made up of four subsystems.

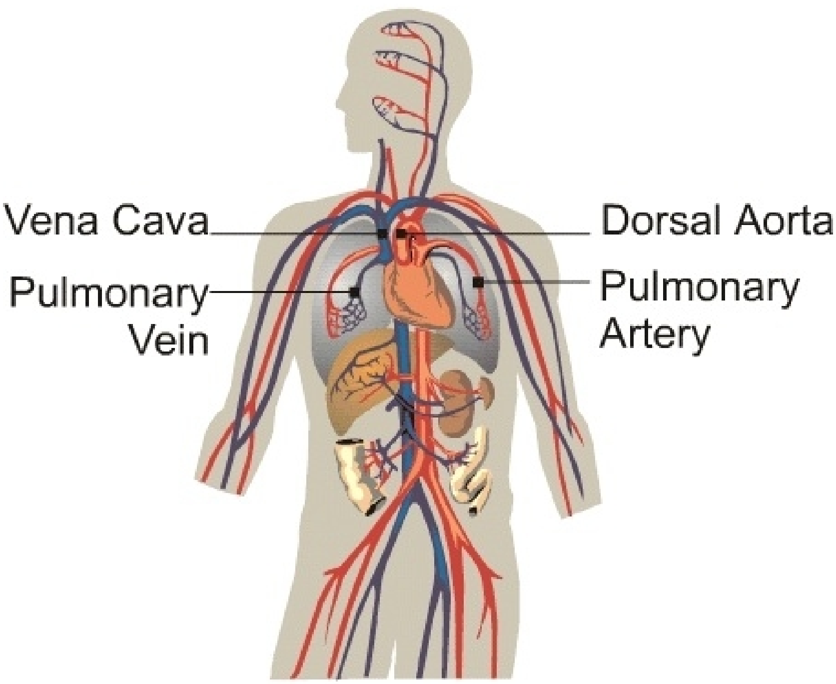


Figure 6.15

General circulation

Arterial Circulation

Arterial circulation is that part of your overall blood circulatory system that involves arteries, like the aorta and pulmonary arteries.

Arteries are blood vessels that carry blood away from your heart. Healthy arteries are strong and elastic. They become narrow between beats of the heart, and they help keep your blood pressure consistent. This helps blood circulate efficiently through your body.

Arteries branch into smaller blood vessels called arterioles. Arteries and arterioles have strong, flexible walls that allow them to adjust the amount and rate of blood flowing to different parts of your body.

Venous Circulation

Venous circulation is the part of your overall blood circulatory system that involves veins, like the vena cavae and pulmonary veins. Veins are blood vessels that carry blood to your heart. Veins have thinner walls than arteries. Veins can increase in width as the amount of blood passing through them increases.

Capillary Circulation

Capillary circulation is the part of your circulatory system where oxygen, nutrients, and waste pass between your blood and parts of your body.

Capillaries connect the arterial and venous circulatory subsystems. Capillaries are very small blood vessels.

The importance of capillaries lies in their very thin walls. Unlike arteries and veins, capillary walls are thin enough that oxygen and nutrients in your blood can pass through the walls to the parts of your body that need them to function normally. Capillaries thin walls also allow waste products like carbon dioxide to pass from your body's organs and tissues into the blood where it's taken away to your lungs.

Pulmonary Circulation

Pulmonary circulation is the movement of blood from the heart to the lungs and back to the heart again. Pulmonary circulation includes both arterial and venous circulation.

Blood without oxygen is pumped to the lungs from the heart (arterial circulation). Oxygen-rich blood moves from the lungs to the heart through the pulmonary veins (venous circulation).

Pulmonary circulation also includes capillary circulation. Oxygen you breathe in from the air passes through your lungs into your blood through the many capillaries in the lungs. Oxygen-rich blood moves through your pulmonary veins to the left side of your heart and out the aorta to the rest of your body. Capillaries in the lungs also remove carbon dioxide from your blood so that your lungs can breathe the carbon dioxide out into the air.

Blood Pressure

Blood pressure (BP) is the force exerted by circulating blood on the walls of blood vessels, and constitutes one of the principal vital signs. The pressure of the circulating blood decreases as blood moves through arteries, arterioles, capillaries, and veins; the term blood pressure generally refers to arterial pressure, i.e., the pressure in the larger arteries, the blood vessels that take blood away from the heart. Arterial pressure is most commonly measured via a sphygmomanometer, which historically used the height of a column of mercury to reflect the circulating pressure. Today blood pressure values are still reported in millimetres of mercury (mmHg), though aneroid and electronic devices do not use mercury.

For each heartbeat, blood pressure varies between systolic and diastolic pressures. Systolic pressure is peak pressure in the arteries, which occurs near the beginning of the cardiac cycle when the ventricles are contracting. Diastolic pressure is minimum pressure in the arteries, which occurs near the end of the cardiac cycle when the ventricles are filled with blood. An example of normal measured values for a resting, healthy adult human is 120 mmHg systolic and 80 mmHg diastolic (written as 120/80 mmHg, and spoken as "one twenty over eighty". Pulse pressure is the difference between systolic and diastolic pressures.

Classification of blood pressure for adults		
Category	systolic, mmHg	diastolic, mmHg
Hypotension	< 90	or < 60
Normal	90 – 119	and 60 – 79
Prehypertension	120 – 139	or 80 – 89
Stage 1 Hypertension	140 – 159	or 90 – 99
Stage 2 Hypertension	$160	or $100

Systolic and diastolic arterial blood pressures are not static but undergo natural variations from one heartbeat to another and throughout the day (in a circadian rhythm). They also change in response to stress, nutritional factors, drugs, disease, exercise, and momentarily from standing up. Sometimes the variations are large. Hypertension refers to arterial pressure being abnormally high, as opposed to hypotension, when it is abnormally low. Along with body temperature, blood pressure measurements are the most commonly measured physiological parameters.

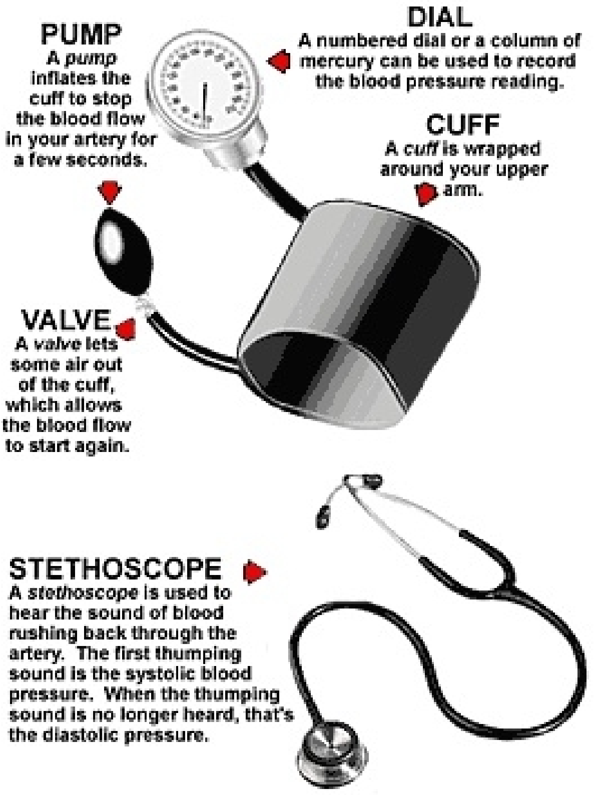


Figure 6.16

Blood pressure measurement

Blood pressure changes during the day. It is lowest as you sleep and rises when you get up. It also can rise when you are excited, nervous, or active.

Still, for most of your waking hours, your blood pressure stays pretty much the same when you are sitting or standing still. That level should be lower than 120/80 mmHg. When the level stays high, 140/90 mmHg or higher, you have high blood pressure. With high blood pressure, the heart works harder, your arteries take a beating, and your chances of a stroke, heart attack, and kidney problems are greater.

What Is Normal Blood Pressure?

A blood pressure reading below 120/80 mmHg is considered normal. In general, lower is better. However, very low blood pressure can sometimes be a cause for concern and should be checked out by a doctor.

Blood

The average person has about 5 litres of blood. It is an important element in delivering essential elements like oxygen and glucose, as well as removing harmful wastes such as carbon dioxide. Our blood is a mixture of two components: plasma and cells.

Plasma, which makes up about 55% of the blood is a straw-coloured liquid that is mainly water (90% by volume). Its primary role is to carry the cells and is the main excretory medium for getting rid of by-products like carbon dioxide.

The cells (about 45% of our blood volume) are mainly red blood cells, which carry haemoglobin and give the blood its distinctive colour; white blood cells; our defensive element against infection and germs which are continuously on the lookout for signs of disease; and platelets, which react with air after a cut and attempt to prevent a loss of blood by clotting.

All blood cells are produced in the bone marrow. If this is damaged it cannot function correctly and a shortage of red cells will result. Leukaemia which is a disqualifying condition for flying, is when there is a shortage of red cells and an abundance of white cells.

Blood donation also leads to a temporary shortage of red blood cells. Although the plasma can be replaced quite quickly (quantity), the formation of red cells is a slower process and can't be speeded up. The quality of blood will be compromised for some time. For this reason, SA-CARs states:

> 91.02.3 (1) No person shall act as a flight crew member of an aircraft –
> (c) within 72 hours following blood donation by such flight crew member.

Anaemia is a condition where there are insufficient red blood cells in the blood. This is because the level of haemoglobin is below the normal range. Haemoglobin is the iron-containing molecule in the red blood cell that carries oxygen around the body. In anaemia, there is less oxygen being delivered to the tissues.

Haemophilia is a condition where the blood does not clot, and can result in a subject bleeding to death.

Pulse Rate

Pulse rate is a measurement of heart rate. It varies from person to person based on fitness and age. It is lower when you are at rest, higher when you exercise. The average resting human heart rate is 70 beats per minute.

Hypertension

A blood pressure of 140/90 mmHg or higher is considered high blood pressure. Both numbers are important. If one or both numbers are usually high, you have high blood pressure.

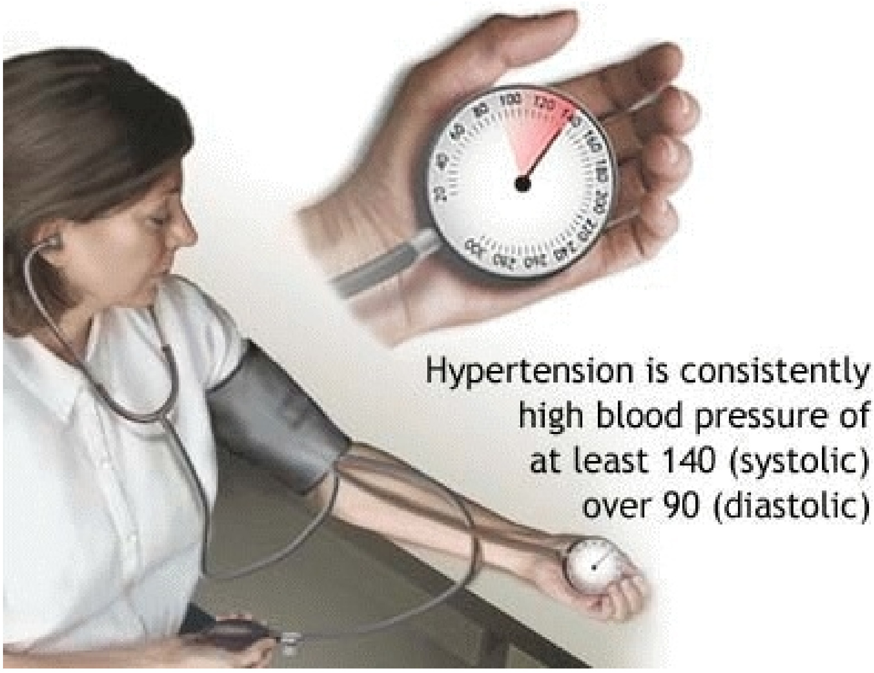


Figure 6.17

Hypertension

If you are being treated for high blood pressure and have repeated readings in the normal range, you still have high blood pressure.

Heart Disease

Your heart is made up of many parts working together to pump blood. In a healthy heart, all the parts work well so that your heart pumps blood normally. Then all parts of your body that depend on the heart to deliver blood also stay healthy.

Heart disease can disrupt a heart's normal electrical system and pumping functions. Diseases and conditions of the heart's muscle make it difficult for your heart to pump blood normally. Damaged or diseased blood vessels make the heart work harder than normal. Problems with the heart's electrical system, called arrhythmias, can make it difficult for the heart to pump blood efficiently.

Coronary Artery Disease

Coronary artery disease (CAD) occurs when the arteries that supply blood to the heart muscle (the coronary arteries) become hardened and narrowed. The arteries harden and narrow due to buildup of a material called plaque on their inner walls. The buildup of plaque is known as atherosclerosis. As the plaque increases in size, the insides of the coronary arteries get narrower and less blood can flow through them. Eventually, blood flow to the heart muscle is reduced, and, because blood carries much-needed oxygen, the heart muscle is not able to receive the amount of oxygen it needs. Reduced or cutoff blood flow and oxygen supply to the heart muscle can result in:

a. Angina. Angina is chest pain or discomfort that occurs when the heart does not get enough blood.

b. Heart attack. A heart attack happens when a blood clot develops at the site of plaque in a coronary artery and suddenly cuts off most or all blood supply to that part of the heart muscle. Cells in the heart muscle begin to die if they do not receive enough oxygen-rich blood. This can cause permanent damage to the heart muscle.

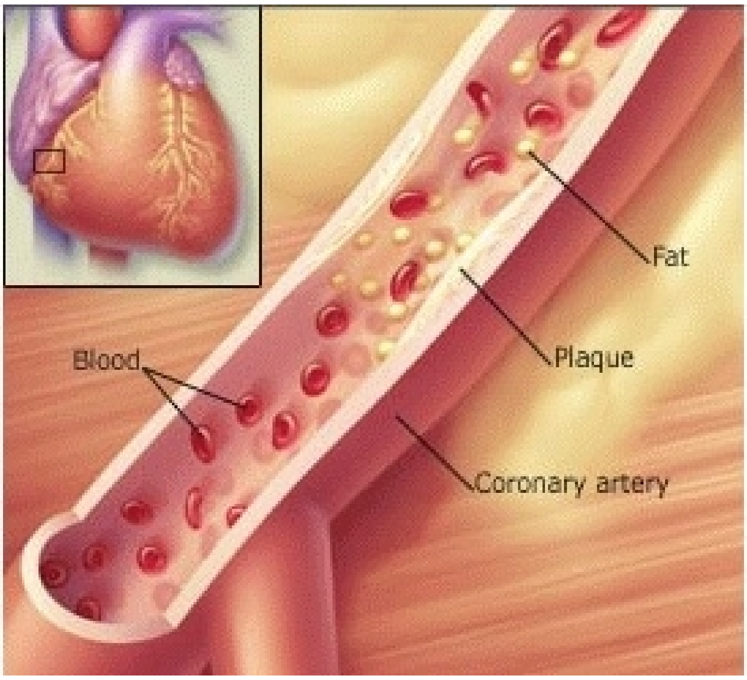


Figure 6.18

Coronary artery disease

Over time, CAD can weaken the heart muscle and contribute to:

a. Heart failure. In heart failure, the heart can't pump blood effectively to the rest of the body. Heart failure does not mean that the heart has stopped or is about to stop. Instead, it means that the heart is failing to pump blood the way that it should.

b. Arrhythmias. Arrhythmias are changes in the normal beating rhythm of the heart. Some can be quite serious.

CAD is the most common type of heart disease. It is the leading cause of death in most countries in both men and women.

Causes of Coronary Artery Disease

Coronary artery disease (CAD) is caused by atherosclerosis (the thickening and hardening of the inside walls of arteries). Some hardening of the arteries occurs normally as a person grows older.

In atherosclerosis, plaque deposits build up in the arteries. Plaque is made up of fat, cholesterol, calcium, and other substances from the blood. Plaque buildup in the arteries often begins in childhood. Over time, plaque buildup in the coronary arteries can:

a. Narrow the arteries. This reduces the amount of blood and oxygen that reaches the heart muscle.

b. Completely block the arteries. This stops the flow of blood to the heart muscle.

c. Cause blood clots to form. This can block the arteries that supply blood to the heart muscle.

Risk factors that cannot be modified:

a. Age. As you get older, your risk for CAD increases.

b. Family history of early heart disease.

Risk factors that can be modified:

a. High blood cholesterol

b. High blood pressure

c. Smoking

d. Diabetes

e. Overweight or obesity

f. Lack of physical activity

Signs and Symptoms of Coronary Artery Disease

The most common symptoms of CAD are:

a. Chest pain or chest discomfort (angina) or pain in one or both arms or in the left shoulder, neck, jaw, or back

b. Shortness of breath

The severity of symptoms varies widely. Symptoms may become more severe as coronary arteries become narrower due to the buildup of plaque (atherosclerosis).

In some people, the first sign of CAD is a heart attack. A heart attack happens when plaque in a coronary artery breaks apart, causing a blood clot to form and block the artery.

Lifestyle Changes

Making lifestyle changes can help treat CAD. For some people, these changes may be the only treatment needed:

a. Eat a healthy diet to prevent or reduce high blood pressure and high blood cholesterol and to maintain a healthy weight

b. Quit smoking, if you smoke

c. Exercise, as directed by your doctor

d. Lose weight, if you are overweight or obese

e. Reduce stress

Angina

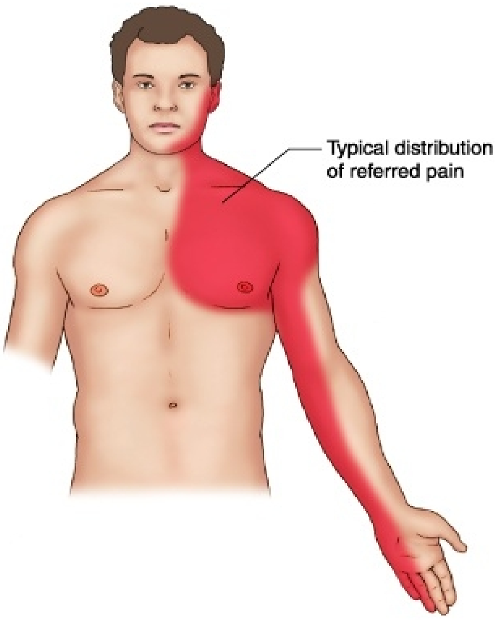


Figure 6.19

Angina

Angina is a symptom of CAD, and is chest pain or discomfort that occurs when your heart muscle does not get enough blood. Angina may feel like pressure or a squeezing pain in your chest. The pain may also occur in your shoulders, arms, neck, jaw, or back. It may also feel like indigestion.

Not all chest pain or discomfort is angina. Chest pain or discomfort can be caused by a heart attack, lung problems (such as an infection or a blood clot), heartburn, or a panic attack. However, all chest pain should be checked by a doctor.

Causes of Angina

Angina is caused by reduced blood flow to an area of the heart. This is most often due to CAD. Sometimes, other types of heart disease or uncontrolled high blood pressure can cause angina.

In CAD, the coronary arteries that carry oxygen-rich blood to the heart muscle are narrowed due to the buildup of fatty deposits called plaque. This is called atherosclerosis. Some plaque is hard and stable and leads to narrowed and hardened arteries. Other plaque is soft and is more likely to break open and cause blood clots. The buildup of plaque on the inner walls of the arteries can cause angina in two ways:

a. By narrowing the artery to the point where the flow of blood is greatly reduced

b. By forming blood clots that partially or totally block the artery

Physical exertion is the most common cause of pain and discomfort from angina. Severely narrowed arteries may allow enough blood to reach the heart when the demand for oxygen is low (such as when you are sitting). But with exertion, like walking up a hill or climbing stairs, the heart works harder and needs more oxygen.

Signs and Symptoms of Angina

Pain and discomfort are the main symptoms of angina. These symptoms

a. Are often described as pressure, squeezing, burning, or tightness in the chest

b. Usually start in the chest behind the breastbone

c. May also occur in the arms, shoulders, neck, jaw, throat, or back

d. May feel like indigestion

Some people say that angina discomfort is hard to describe or that they can't tell exactly where the pain is coming from. Symptoms such as nausea, fatigue, shortness of breath, sweating, light-headedness, or weakness may also occur.

Heart Attack

A heart attack occurs when blood flow to a section of heart muscle becomes blocked. If the flow of blood isn't restored quickly, the section of heart muscle becomes damaged from lack of oxygen and begins to die.

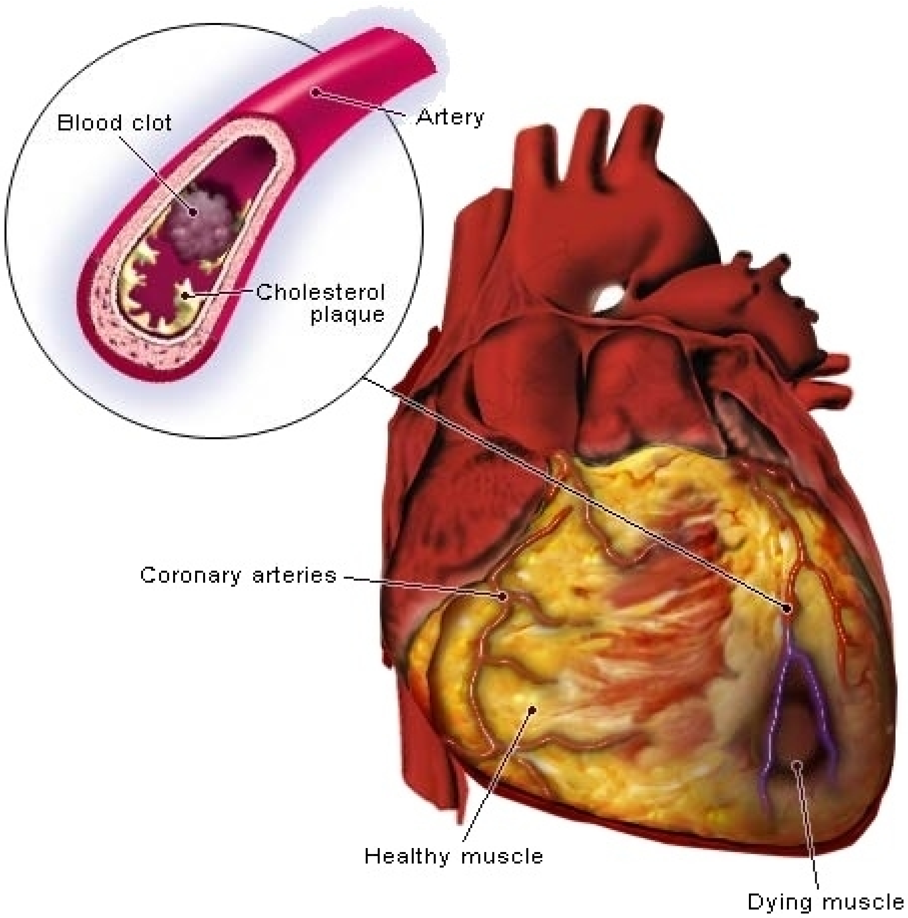


Figure 6.20

Heart attack

Heart attack is a leading killer of both men and women in most countries around the world. Fortunately, today there are excellent treatments for heart attack that can save lives and prevent disabilities. Treatment is most effective when started within 1 hour of the beginning of symptoms. If you think you or someone you're with is having a heart attack, call a doctor right away.

Heart attacks occur most often as a result of a condition called coronary artery disease (CAD). In CAD, a fatty material called plaque builds up over many years on the inside walls of the coronary arteries (the arteries that supply blood and oxygen to your heart). Eventually, an area of plaque can rupture, causing a blood clot to form on the surface of the plaque. If the clot becomes large enough, it can mostly or completely block the flow of oxygen-rich blood to the part of the heart muscle fed by the artery.

During a heart attack, if the blockage in the coronary artery isn't treated quickly, the heart muscle will begin to die and be replaced by scar tissue. This heart damage may not be obvious, or it may cause severe or long-lasting problems.

Severe problems linked to heart attack can include heart failure and life-threatening arrhythmias (irregular heartbeats). Heart failure is a condition in which the heart can't pump enough blood throughout the body. Ventricular fibrillation is a serious arrhythmia that can cause death if not treated quickly.

Get Help Quickly

Acting fast at the first sign of heart attack symptoms can save your life and limit damage to your heart. Treatment is most effective when started within 1 hour of the beginning of symptoms.

The most common heart attack signs and symptoms are:

a. Chest discomfort or pain, uncomfortable pressure, squeezing, fullness, or pain in the centre of the chest that can be mild or strong. This discomfort or pain lasts more than a few minutes or goes away and comes back.

b. Upper body discomfort in one or both arms, the back, neck, jaw, or stomach.

c. Shortness of breath may occur with or before chest discomfort.

d. Other signs include nausea (feeling sick to your stomach), vomiting, lightheadedness or fainting, or breaking out in a cold sweat.

Other Names for a Heart Attack

As with other medical conditions, doctors seem to pull out the stops when giving them names. Heart attacks are also known as: Myocardial infarction or MI, Acute myocardial infarction or AMI, Acute coronary syndrome, Coronary thrombosis, Coronary occlusion

Figure 6.21 shows a normal artery with normal blood flow (left hand side) and an artery containing plaque buildup (right hand side). In the sketch, this is related to age, but unhealthy younger people can be well over to the right at an early age. The blocked blood flow prevents oxygen-rich blood from reaching the part of the heart muscle fed by the artery. The lack of oxygen damages the heart muscle. If the blockage isn’t treated quickly, the damaged heart muscle begins to die.

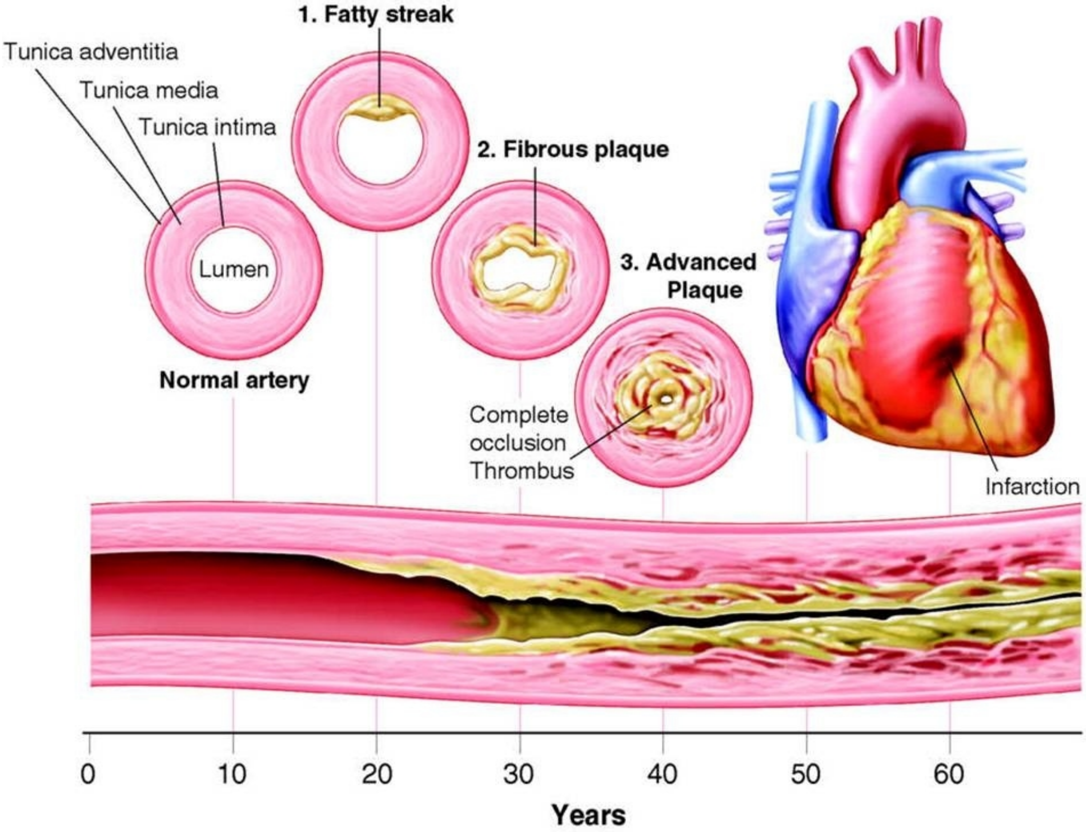


Figure 6.21

Plaque build up over time

Hypotension, or low blood pressure

Hypotension is abnormally low blood pressure. Normal blood pressure is a reading of less than 120/80 mmHg. Hypotension is blood pressure that is lower than 90/60 mmHg.

Some people have low blood pressure all the time. They have no signs or symptoms and their low readings are normal for them. In other people, blood pressure drops below normal because of some event or medical condition. Hypotension is a medical concern only if it causes signs and/or symptoms such as dizziness, fainting, or, in extreme cases, shock.

The body is very sensitive to changes in blood pressure. Special cells in the arteries, called baroreceptors, can sense if blood pressure begins to rise or drop. When the baroreceptors sense a rise or drop in blood pressure, they cause certain responses to occur throughout the body in an attempt to bring the blood pressure back to normal.

For example, if you stand up quickly, the baroreceptors will sense a drop in your blood pressure. They quickly take action to make sure that blood continues to flow to the brain, kidneys, and other important organs. The baroreceptors cause the heart to beat faster and harder. They also cause the small arteries (arterioles) and veins (the vessels that carry blood back to the heart) to narrow.

Most forms of hypotension happen when the body can’t bring blood pressure back to normal or can’t do it fast enough.

In a healthy person, hypotension without signs or symptoms is usually not a problem and requires no treatment. Doctors will want to identify and treat any underlying condition that is causing the hypotension, if one can be found. Hypotension can be dangerous if a person falls because of dizziness or fainting.

Shock, a severe form of hypotension, is a life-threatening condition that is often fatal if not treated immediately. Shock can be successfully treated if the cause can be found and the right treatment provided in time.

The Respiratory System

The primary function of the respiratory system is to supply the blood with oxygen in order for the blood to deliver oxygen to all parts of the body. The respiratory system does this through breathing. When we breathe, we inhale oxygen and exhale carbon dioxide. This exchange of gases is the respiratory system's means of getting oxygen to the blood.

Respiration is achieved through the mouth, nose, trachea, lungs, and diaphragm. Oxygen enters the respiratory system through the mouth and the nose. The oxygen then passes through the larynx (where speech sounds are produced) and the trachea which is a tube that enters the chest cavity. In the chest cavity, the trachea splits into two smaller tubes called the bronchi. Each bronchus then divides again forming the bronchial tubes. The bronchial tubes lead directly into the lungs where they divide into many smaller tubes which connect to tiny sacs called alveoli. The average adult's lungs contain about 600 million of these spongy, air-filled sacs that are surrounded by capillaries. The inhaled oxygen passes into the alveoli and then diffuses through the capillaries into the arterial blood. Meanwhile, the waste-rich blood from the veins releases its carbon dioxide into the alveoli. The carbon dioxide follows the same path out of the lungs when you exhale.

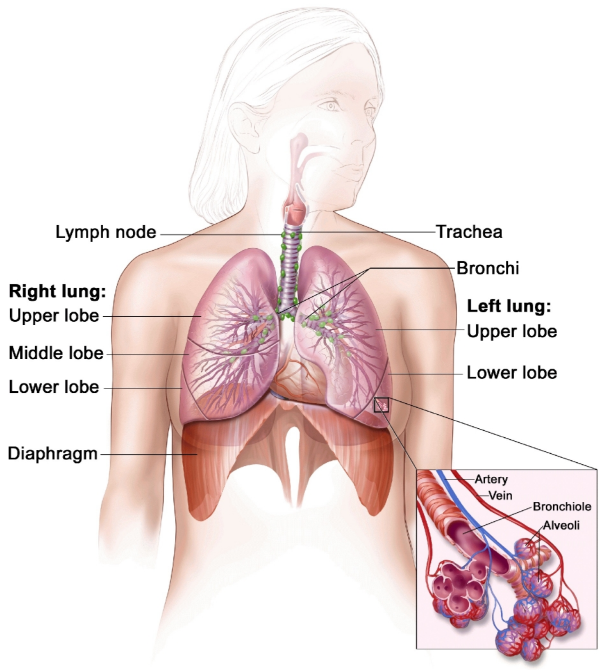


Figure 6.22

Lung Structure

The diaphragm's job is to help pump the carbon dioxide out of the lungs and pull the oxygen into the lungs. The diaphragm is a sheet of muscles that lies across the bottom of the chest cavity. As the diaphragm contracts and relaxes, breathing takes place. When the diaphragm contracts, oxygen is pulled into the lungs. When the diaphragm relaxes, carbon dioxide is pumped out of the lungs. This happens about 12 - 20 times per minute, with an average of about 15 accepted as the average breathing rate.

Respiration

Respiration is the transport of Oxygen from the outside air to the cells within tissues and the transport of carbon dioxide in the opposite direction.

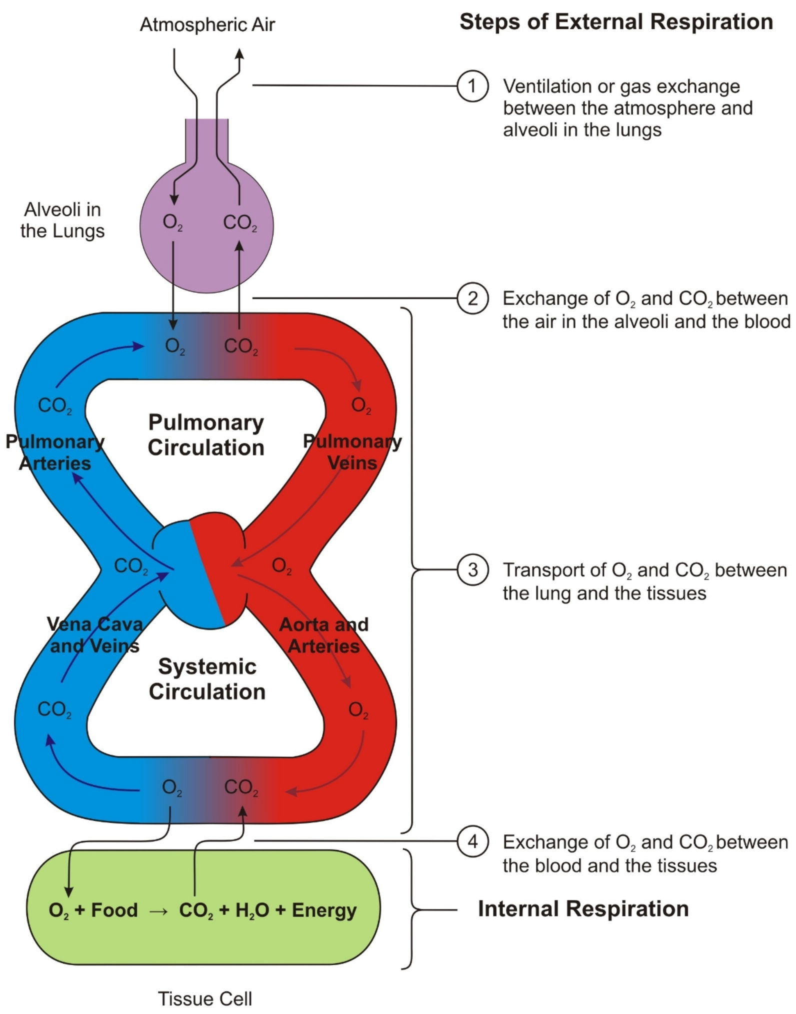


Figure 6.23

External and Internal Respiration

In humans, respiration of oxygen includes four stages:

a. Ventilation, moving of the ambient air into and out of the alveoli of the lungs.

b. Pulmonary gas exchange, exchange of gases between the alveoli and the pulmonary capillaries.

c. Gas transport, movement of gases within the pulmonary capillaries through the circulation to the peripheral capillaries in the organs, and then a movement of gases back to the lungs along the same circulatory route.

d. Peripheral gas exchange, exchange of gases between the tissue capillaries and the tissues or organs.

Take Dalton’s Law when considering a climb. There will be a reduction in atmospheric pressure. This reduction in pressure is important as it has a direct effect on the amount of oxygen that is available for us to use.

This whole process of inhaling oxygen and exhaling carbon dioxide is also referred to as the gas transfer - oxygen to the tissues, and carbon dioxide back to the atmosphere.

The body has only the capability of carrying a small store of oxygen, and this has to be continuously replenished by breathing. In order for the oxygen to pass from the lung to the blood, there must be sufficient oxygen present, and the atmospheric pressure must be high enough to cause the oxygen to transfer from the air in the lung into the blood. The amount of oxygen stored in the blood is low, so if the partial pressure of oxygen in the lungs is greater than that in the blood, this transfer will take place. The word used is diffusion - the oxygen diffuses into the blood.

As long as there is a pressure gradient between the pressure of oxygen in the lungs and that in the blood, this process will continue, and life goes on normally. By the same token, as the partial pressure of carbon dioxide in the blood is higher than that in the lungs and atmospheric air, the carbon dioxide diffuses back into the lungs from the blood, and finally into the atmosphere (Figure 6.24). If the pressure at the entry point (top left for oxygen) drops, it stands to reason that the pressures will drop all the way to the right. When the oxygen pressure at bottom right drops to zero, the tissues are no longer receiving oxygen.

Let us look at a few numbers now:

a. We know that the pressure of the atmosphere, according to the International Standard Atmosphere (ISA) is 1013,25 hPa. We also know that oxygen makes up 21% of that. We can safely say therefore, that the partial pressure (Dalton's Law) of the oxygen is approximately 213 hPa. This is more than enough to keep us going at sea level.

b. At 18 000 feet the pressure of the atmosphere drops to about half of the sea level pressure, or roughly 107 hPa (21% of 506 hPa).

To make matters worse, the pressure of the oxygen in our lungs is nowhere near the pressure of the oxygen in the atmosphere. This is due to the presence of water vapour and carbon dioxide in our lungs. There is certainly water vapour and carbon dioxide in the atmosphere, but the quantities are minute compared to those in the lungs. This is due to the fact that when we breathe in, the air is warmed to body temperature (about 37°C) and the warmed air can hold more water vapour. In this case it is about 63 hPa of the total pressure in the lung.

This amount is largely unaffected by any ascent into colder air as the air in the lungs is warmed to the same temperature irrespective of outside air temperature. The amount of carbon dioxide present in the lungs is about 53 hPa at sea level. This stays fairly constant up to about 8 - 10000 feet, and then slowly reduces, but remains much higher than the carbon dioxide in the atmosphere. The table below gives an idea of what is present in the lungs - referred to as the Alveolar Gas (see also Figure 6.25). Alveoli are the very small sacs in the lungs from which the oxygen diffuses to the blood.

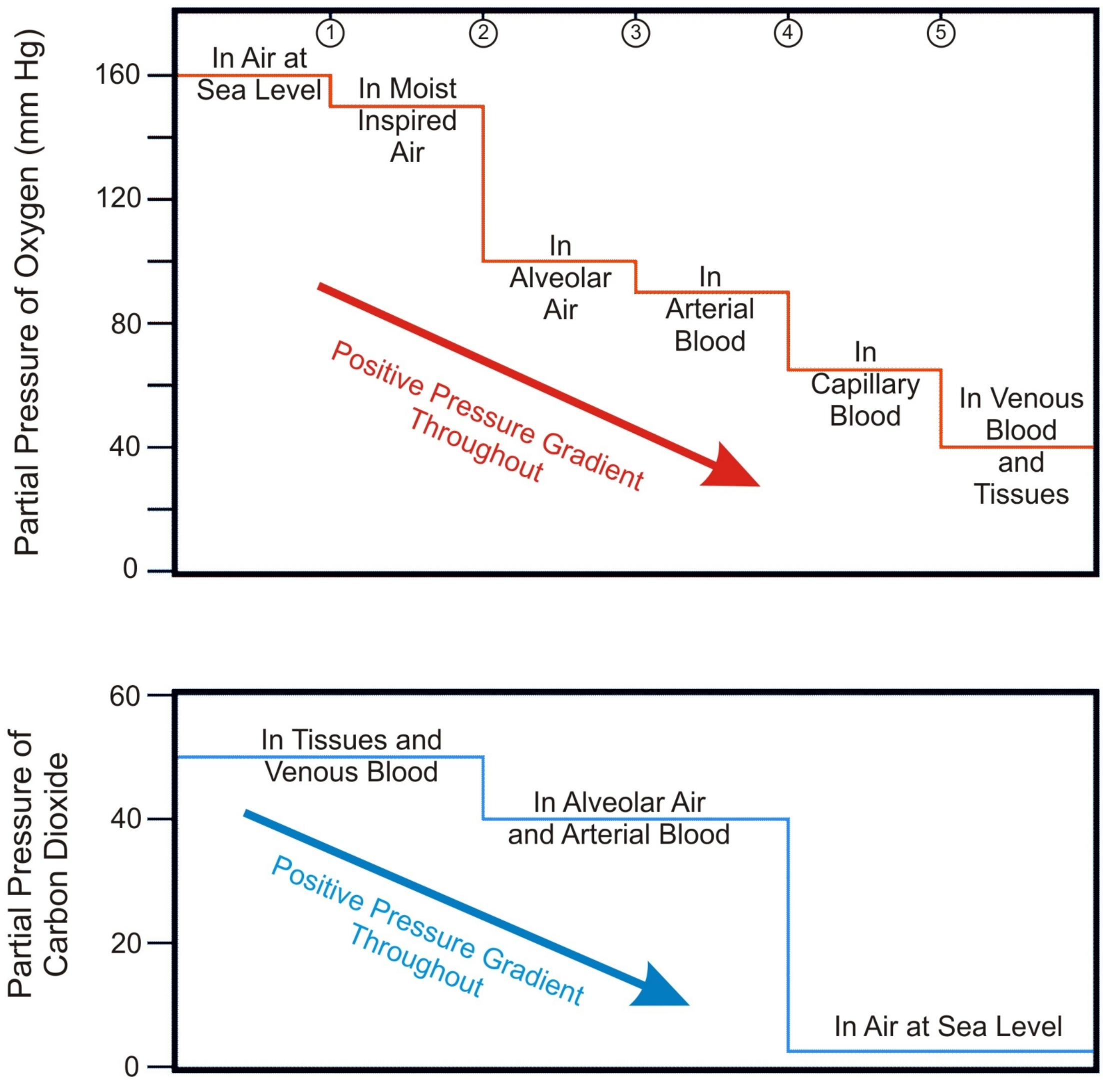


Figure 6.24

Internal Respiration Pressure Gradients

Table 6.1. Typical Partial Pressures of Alveolar Gases when Breathing at Various Altitudes

Altitude in feet	Partial pressure (in hPa) in Alveolar Gas of:			
	Water Vapour	Oxygen	Carbon Dioxide	Nitrogen
0	63	133	53	764
8 000	63	87	53	564
18 000	63	53	37	354
35 000	63	24	16	137

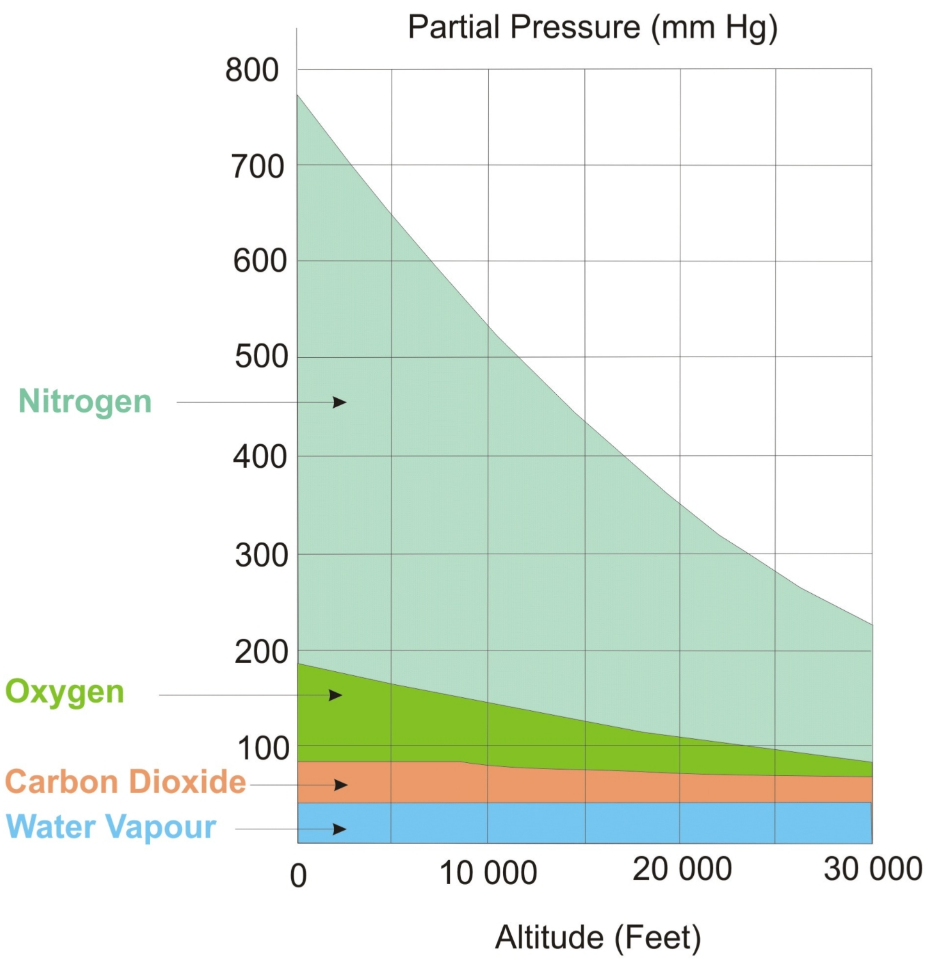


Figure 6.25

The Constituents of Alveolar Air

Hypoxia

From Table 6.1 it can be seen that the pressure of oxygen available in the lungs decreases as altitude is gained. When the partial pressure of the oxygen drops below 70 - 80 hPa we have a problem. There is simply not enough oxygen available for the tissues to do their work efficiently. It has already been stated that oxygen is one of the most important materials required for the performance of normal function by the human being. A reduction in the supply of oxygen with sufficient partial pressure results in a condition called hypoxia.

Hypoxia almost always results in a deterioration of most functions and may cause death. The human being is extremely sensitive and vulnerable to the effects of deprivation of oxygen. The reduction of the partial pressure of oxygen in the atmosphere associated with a climb to an altitude of 8,000 feet produces a detectable impairment of mental performance. If the pilot was suddenly subjected to a cabin altitude of 50,000 feet, where the partial pressure of oxygen is about 13 hPa, unconsciousness would occur in 10 seconds and death in 4 - 6 minutes.

It is generally recognized that the most serious single hazard to man during flight is the reduction of the partial pressure of oxygen resulting from a climb to altitude.

Failure of cabin-pressurisation so that the individual has to breathe air at high altitude quickly leads to incapacitation and perhaps death. The risks are greater in aviation because a reduction in the amount of oxygen available may not be fatal in itself, but may have fatal results because of deterioration of performance in an individual leading to loss of control of an aircraft.

In the past, a shortage of oxygen has taken a regular toll of both lives and aircraft. Although improvements in the performance and reliability of cabin pressurization and oxygen delivery systems have greatly reduced incidents and accidents due to hypoxia, pilots must always remain aware of the inherent dangers.

The causes of hypoxia in flight are:

a. Ascent to altitude without supplemental oxygen.

Part 91.04.18 states that in the case of a pressurised aircraft: No owner or operator of a pressurised aircraft shall operate the aircraft unless such aircraft is equipped with the supplemental oxygen as prescribed in Document SA-CATS-OPS 91, while Part 91.04.19 states that in the case of as non-pressurised aircraft: No owner or operator of a non-pressurised aircraft shall operate the aircraft at altitudes above 10 000 feet and up to 12 000 feet for longer than 60 minutes, or above 12 000 feet, unless such aircraft is equipped with the supplemental oxygen as prescribed in Document SA-CATS-OPS 91.

b. Failure of personal breathing equipment to supply oxygen at an adequate concentration and/or pressure.

c. Decompression of pressure cabin at high altitude.

The time that it takes for the effects of hypoxia to become evident are related to the manner in which the condition was induced. A slow rate of climb (2000 - 3000 feet per minute) will induce the condition very slowly. If a pilot had been on oxygen breathing apparatus, and lost the equipment due to failure, the effects would show quicker. The worst case scenario is if there is sudden decompression of a pressurised aircraft.

Although breathing air during a steady ascent at 2000 - 3000 feet per minute is an uncommon cause of hypoxia in these days, it is necessary to understand the changes induced by hypoxia in this manner since the relatively slow rate of climb allows a semi-steady state to be maintained during the ascent.

Symptoms and Signs of Hypoxia

The symptoms and signs of hypoxia are extremely variable. The speed and order of appearance of signs and of the severity of symptoms produced by breathing air at altitude depend upon the altitude, the duration of the exposure and rate of either ascent or failure of the oxygen supply at altitude. The other major factor affecting the intensity of hypoxia at altitude is the degree of physical exercise; exercise markedly intensifies the effects of a given degree of hypoxia. Fatigue, exposure to cold, ingestion of alcohol or certain stimulant drugs such as Benzedrine also increase the severity of the disturbances induced by a given intensity of hypoxia. Finally there is considerable individual variability in the symptoms and effects of hypoxia. Generally the higher the altitude, the more marked the symptoms. Rapid rates of climb, however, allow higher altitudes to be reached before severe symptoms occur. In these circumstances, unconsciousness may occur unexpectedly before any or many of the symptoms of hypoxia appear.

> The biggest problem with hypoxia is that the subject is least aware of the problem
> Symptoms are usually seen by someone else who is not yet hypoxic

The effects of a slow climb (less than 4000 feet per min) to altitude whilst breathing air are as follows:

a. Altitudes up to 10000 Feet (Altitudes are Cabin Altitude, and are feet above sea level). The seated individual (unless he is carrying out heavy exercise) has no symptoms. His ability to perform most complex tasks is unimpaired. The speed with which he can react to new conditions is however significantly impaired at altitudes above 6000 - 8000 feet. It is possible to show in a decompression chamber that the ability to detect objects in conditions of low lighting is impaired at altitudes above 5000 - 6000 feet. This degree of impairment however has no practical implications - night vision is only impaired significantly when the altitude exceeds 12000 - 14000 feet.

b. Altitudes between 10,000 and 15,000 Feet. The resting individual has little or nothing in the way of symptoms but his ability to perform skilled tasks such as aircraft control and navigation is impaired, the impairment increasing with altitude above 10000 feet. The individual is frequently unaware of the hypoxia or of the impairment of performance which it produces. Indeed he may well believe that he is performing better than usual! Physical exercise, particularly at altitudes above 12000 feet, frequently produces mild symptoms, especially breathlessness. Exposure to these altitudes for longer than 10 - 20 minutes often induces a severe headache.

c. Altitudes between 15000 and 20000 Feet. Above about 15,000 feet, symptoms of hypoxia occur even in individuals at rest. There is marked impairment of performance, even of simple tasks, together with a loss of critical judgement and will power. Thinking is slowed, there is muscular in-coordination with trembling and clumsiness and marked changes in the emotional state. Thus the individual may become hilarious, combative or sullen. He may become physically violent. Again he usually has no insight into his condition; an effect which makes hypoxia such a potentially dangerous hazard in aviation. Darkening of vision is a common symptom although generally the subject is unaware of the change until oxygen is breathed, when there is a marked apparent brightening of level of illumination. Hearing is not usually markedly impaired until the hypoxia becomes severe. Physical exertion greatly increases the severity of all the effects. It often causes unconsciousness.

d. Altitudes above 20000 Feet. Breathing air at altitudes above 20000 feet results in severe symptoms even in individuals at rest. Mental performance and comprehension decline rapidly and unconsciousness supervenes with little warning. Jerking of the upper limbs occurs quite often before consciousness is lost and convulsions may occur after unconsciousness has occurred. Exertion rapidly leads to unconsciousness.

In moderate and severe hypoxia the depth and rate of breathing are increased and this effect can usually be seen on exposure to breathing air at altitudes above 15,000 - 18,000 feet. Above 18,000 feet the high concentration of haemoglobin which has given up its oxygen in the capillaries of the skin gives rise to blueness of the lips, tongue and face as well as the skin of the limbs. This is known as cyanosis, and is most noticeable in the finger nail beds.

Time of Useful Consciousness (TUC)

Interruption of the supply of supplemental oxygen at altitudes above 10,000 feet with reversion to breathing air is a more frequent cause of hypoxia in flight than ascent without added oxygen. As the altitude is increased the times between the reversion to breathing air and the consequent impairment of performance, followed at the higher altitudes by loss of consciousness, rapidly decrease. The time which elapses between sudden reversion to breathing air and loss of useful consciousness, ie the point at which an individual is no longer able to carry out his task, is very variable, especially at altitudes below 28000 - 30000 feet (see Figure 6.26).

To make things a bit easier, the following can be used as a guideline to answering any questions which may come your way:

20 000 feet	30 minutes
Above 30 000	Less than 1 minute, ie. Seconds
Above 40 000 feet	Single digit seconds, ie. Less than 10

Altitude	Time of Useful Consciousness
45 000 feet	9 - 15 seconds
40 000 feet	15 - 20 seconds
35 000 feet	30 - 60 seconds
30 000 feet	1 - 2 minutes
28 000 feet	2½ - 3 minutes
25 000 feet	3 - 5 minutes
22 000 feet	5 - 10 minutes
20 000 feet	30 minutes or more

Figure 6.26

Time of Useful Consciousness

Hypoxia can be prevented by the use of supplemental oxygen once the cabin altitude is above 10 000 ft. If the cabin altitude rises above 10 000 ft, then the partial pressure of oxygen will reduce. The percentage of oxygen will have to gradually increased to offset the drop in partial pressure. The percentage of oxygen will eventually have to reach 100%, and this occurs at an altitude of 33 700 ft (30 000 ft is used to allow for changes in sea level pressure). At this stage, the partial pressure of the 100% oxygen that is being breathed is the same as normal air at sea level.

Above 30 000 ft the partial pressure of oxygen will gradually reduce, in the same way as the partial pressure of oxygen reduces between sea level and 10000 ft. at 40 000 ft the 100% oxygen will be providing much the same as normal air at 10 000 ft. above this altitude, 100% oxygen will not be enough, and the oxygen will have to be provided under pressure, a somewhat rare occurrence for the recreational pilot.

Cabin Decompression

Cabin decompression is something which can only occur in a pressurized aircraft, and this loss of cabin pressurization can only occur in flight. The rate at which the air leaves the pressurized cabin depends upon a number of factors: the volume of the cabin; the size of the rupture; and the pressure differential between cabin and ambient altitude. Once again, this is something that does not affect many recreational pilots, but what can happen is important - if you win the Lotto and can afford something special.

The rate of loss may be very slow with the pilot recognizing the problem and making appropriate height reductions before anything dramatic happens. Very occasionally there is a rapid decompression such as may result from the loss of a window or door, or terrorist action (in June 1990 a British Airways BAC 1-11 en route from Birmingham suffered the loss of the captain's windshield and a pilot was almost lost when sucked out of the cockpit). In that event all the occupants of the aircraft are very abruptly exposed to the full conditions of high altitude with all the risks of hypoxia, freezing temperatures and decompression sickness. The aircraft must rapidly descend to a safer altitude and all on board may need to use emergency oxygen to avoid hypoxia.

In cases of rapid decompression the altitude in the cabin may actually rise above that of the aircraft. This is brought about by an effect known as aerodynamic suction whereby air on the outside, passing quickly over the defect in the aircraft hull, because of its cambered shape, has a Venturi effect on the remaining air in the cabin. Therefore further air may be sucked out and the cabin altitude rise still higher. The precise degree to which this may occur depends on the position of the defect in the airstream and the height of the aircraft, but may amount to as much as 5000ft in pressure terms.

Hyperventilation

Hyperventilation is over breathing, either in an attempt to get more oxygen, or as a result of anxiety. During normal respiration, the carbon dioxide which is produced is transferred to the atmosphere. The carbon dioxide in the blood is one of the triggers for breathing. When there is an increase in the carbon dioxide content in the blood, the brain is triggered and respiration increases. As soon as carbon dioxide levels are back to normal, normal breathing is restored.

This is the natural breathing process. The respiratory centre in the brain is extremely sensitive to small changes in the partial pressure of carbon dioxide and continuously adjusts the breathing rate to keep the partial pressure of this gas at the normal level.

When the partial pressure of the carbon dioxide drops below the normal values, it is termed hyperventilation. This can be caused voluntarily by a person breathing too fast and deep when it is not necessary, anxiety due to stress being a common cause. You have probably found yourself breathing faster when concentrating on a task given u by your instructor.

The excessive removal of carbon dioxide from the blood and tissues which results from hyperventilation results in the following symptoms:

a. Tingling in the hands, the feet and the lips.

b. Spasm of the muscles of the hands and feet.

c. Vague feeling of unreality.

d. Light-headedness and dizziness.

e. Faintness.

f. If prolonged, unconsciousness. The anxiety will have been removed and breathing will quickly return to normal, but an unconscious pilot on his own in an aircraft is a serious problem!

As the breathing rate is reduced, so the pulse rate is also slowed. This results in hypoxia-like symptoms, so hyperventilation is a condition to be avoided. To reduce the likelihood of hyperventilation occurring in flight the following points should be observed:

a. Learn to breathe in a normal manner particularly when carrying out tasks which are known to predispose to hyperventilation.

b. Beware of the tendency to over-breathe during periods of intense concentration or tension.

c. Do not attempt to overcome suspected hypoxia by voluntary over-breathing.

Breathing into a paper bag will result in more carbon dioxide being inhaled than what would normally be the case when breathing atmospheric air. Do not let a subject do this for too long, as the opposite could occur - too much carbon dioxide in the blood. This will result in a slowing down of the pulse rate, creating exactly the same problem as before. Get a subject to calm down and speak normally is always the best option.

It is possible to confuse the symptoms of hypoxia and hyperventilation. When symptoms are experienced at cabin altitudes at which hypoxia could occur, always assume the worst, and take hypoxia to be the cause. If the symptoms occur at an altitude where hypoxia is not a consideration (below 10 000 ft), regulate the rate and depth of respiration to reduce over breathing. This will restore the balance in the blood and the symptoms should be alleviated.

Accelerations

Even though you may never plan to do any aerobatics, you need to know about the effects of accelerations on your body. Even the slightest acceleration could lead to disorientation in a low-speed take-off, while you may be rendered unconscious in a high-speed turn. The ability of the body to cope will be determined by a number of factors - the intensity of the acceleration, and the duration being the most important. As far as duration is concerned, an acceleration of more than one second is regarded as long. Short term accelerations usually relate to a crash type situation where a person is subjected to very high accelerative forces, but only for a split second.

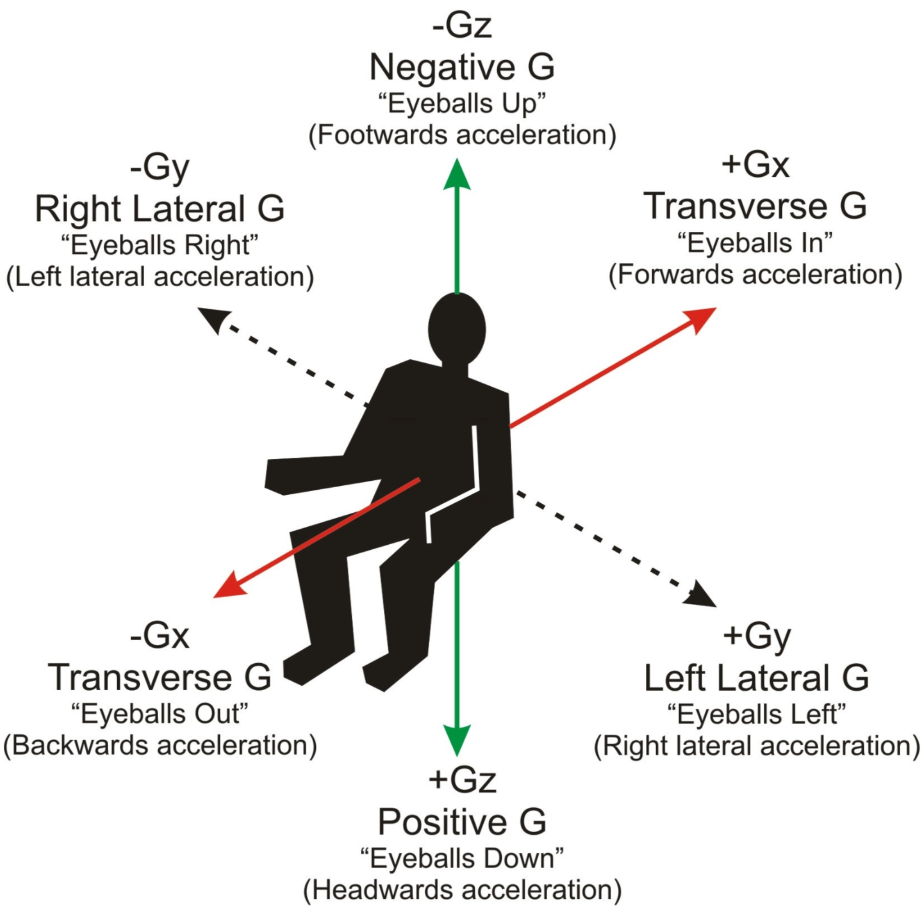


Figure 6.27

The G Axes

Let us look at the G-forces that affect pilots. We all experience the force of gravity (g), which is 32.2 ft/sec^2. When we speak of any acceleration in respect of the three planes relative to the body, we use G. These planes are the longitudinal (head to toe) which is Gz, the transverse (fore/aft) which is Gx, and the lateral (left/right) which is Gy. These forces can be positive or negative. By convention, any acceleration from feet to head is called -Gz, while acceleration from head to feet is +Gz. Figure 6.27 gives an indication of the six forces than come into play. The effect of this acceleration is the displacement of fluids and tissues. It is important to understand that the displacement is caused by the inertia of the tissues and will be opposite in direction to the applied acceleration force. For example, a forward acceleration will result in a reactionary force directly rearwards. Decelerate and the force is forwards, pulling you out of your seat. A vertical acceleration upwards will result in an opposite force downwards, forcing you into the seat, while a downwards acceleration will have floating around in the cockpit if you weren't strapped in. Anyone who hasn't had the pleasure of doing aerobatics should try out a really hairy roller coaster ride to experience G!

Only Gx and Gz are of significance to the civilian pilot and the most significant result of Gx is disorientation. When people talk of positive or negative G they are usually referring to Gz.

The Effects of G

G tolerance varies greatly with the individual. Because the symptoms are caused by the displacement of blood and tissues, we would expect that a pilot with good muscle tone would have a better tolerance. This is correct. Tolerance is lowered by obesity, ill health, low blood pressure, pregnancy and many medications. It may vary from day to day in relation to fatigue, smoking, hypoxia or hangovers.

Figure 6.28

Positive G on a Roller Coaster

As far as short term accelerations are concerned, the human body can tolerate forces of a maximum of about 25G in the vertical axis (Gz) and up to 45G in the fore/aft axis (Gx). This is because of the relative strengths of different parts of the body, and the displacement that could take place. Exceeding these values will cause injury or death.

Don't get too excited about being able to survive 45G in the fore/aft axis. The seat will normally come adrift long before that, and seat harnesses would have to have a breaking strain in excess of 4½ tons for a 90 kg pilot or passenger. You survive the crash landing - and then your seat or harness let you down!

Long duration accelerations are more important. Let us consider a 60° angle of bank turn. It requires 2G to maintain a level turn, and all are aware of the downward force pressing one into the seat. Increase that to 4G and things start to get really difficult.

At 4G the weight of the body (and each of its components) increases fourfold. A 90 kg pilot now effectively weighs 360 kg. It becomes very difficult to lift the hands to reach for a switch, and to keep the head up takes a lot of effort. Worse still, the blood's weight has also increased relatively, and it pools in the lower parts of the body, re-circulation of blood becomes difficult, and the heart is not able to keep the brain and eyes supplied with the right amount of oxygen enriched blood. The first indication that something is amiss is called a Grey out. Because the fine blood vessels in the periphery of the eyeball are the first to lose blood, vision from the periphery of the eye fades away. It is much like looking through a thin tube - you can see directly ahead, but can see nothing to the sides.

If this is maintained for a longer duration, or the level of acceleration increased, the blood flow to the eyes will stop altogether and a Black out occurs - all vision is lost. Relieving the G force will quickly restore sight, but the subject may be disorientated for a few seconds due to the fact that the aircraft would have turned while vision was lost, and it would take some time to find one's bearings again. If the G forces are maintained, unconsciousness will occur.

An untrained person will normally black out at about 3,5G but it is possible to use straining manoeuvres to delay black out until 7 or 8G. By tensing the stomach muscles, the downward flow of blood is prevented for a while, but the subject will eventually succumb.

A persons ability to cope with these G forces is reduced by a number of factors. These include hypoxia, hyperventilation, heat, smoking, alcohol, obesity, and hypoglycaemia (low blood sugar).

Negative G on the other hand, inverted flight or bunting the aircraft, is much more uncomfortable, and the body can only sustain small amounts. The maximum level is about -3G, and then only for short durations. A condition called Red out occurs when the bottom eyelid pushes up over the eye. It is light passing through the eyelid that gives the red out it’s name. Blood rushing to the head causes facial pain and headaches, and small blood vessels in the brain, face and eyes could burst.

Vision

All pilots must have extremely good eyesight to operate an aircraft safely. Vision is the most important of our senses, and is the one we rely on most. As far as the wearing of spectacles is concerned, if you have any eye defect which can be corrected, it is acceptable. As we age there will be some defects which may occur, and these may also be corrected with spectacles.

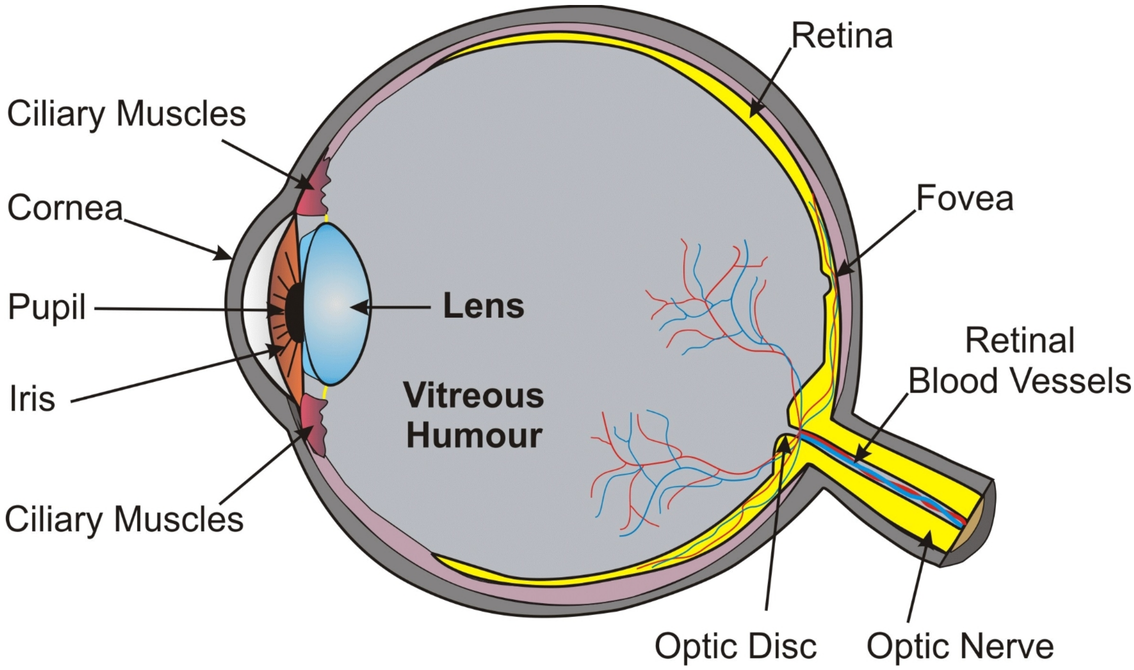


Figure 6.29

The eye

The eye is basically a camera. The eyelids are the shutters, the light then passes through the cornea before reaching the lenses which focus the image, and by adjusting the iris, we change the size of the pupil and adjust the amount of light entering the eye. The whole image that we see falls on the retina at the back of the eye, and the light that falls onto the retina is converted to nerve impulses which then pass to the brain via the optic nerve (Figure 6.29).

The first stage of sight begins with the fact that all objects emit or reflect light in all directions. The light rays fall onto the cornea and the process of refraction begins. This is the start of our focussing ability. About 70% of refraction, and therefore our focus, takes place in the cornea. The rest is taken care of by the lens (about 30%). Our ability to focus is termed accommodation (Figure 6.30), and relates to the ability of the lens to change shape in order to allow both near and distant vision.

In conditions of good lighting the image falls onto the central area of the retina. This area has a concentration of nerve endings called cones which can detect fine detail. To the periphery of the eye the nerve endings are rods which are sensitive to light and are used in conditions of poor lighting, such as night flying. If you want to see an object best in good lighting, look straight at it. The image will be focussed on the cones. If the image falls on the optic nerve, then nothing will be visible and this known as the “blind spot”. This could present a problem with only one eye (monocular vision), but using both eyes (binocular vision) this problem is usually solved.

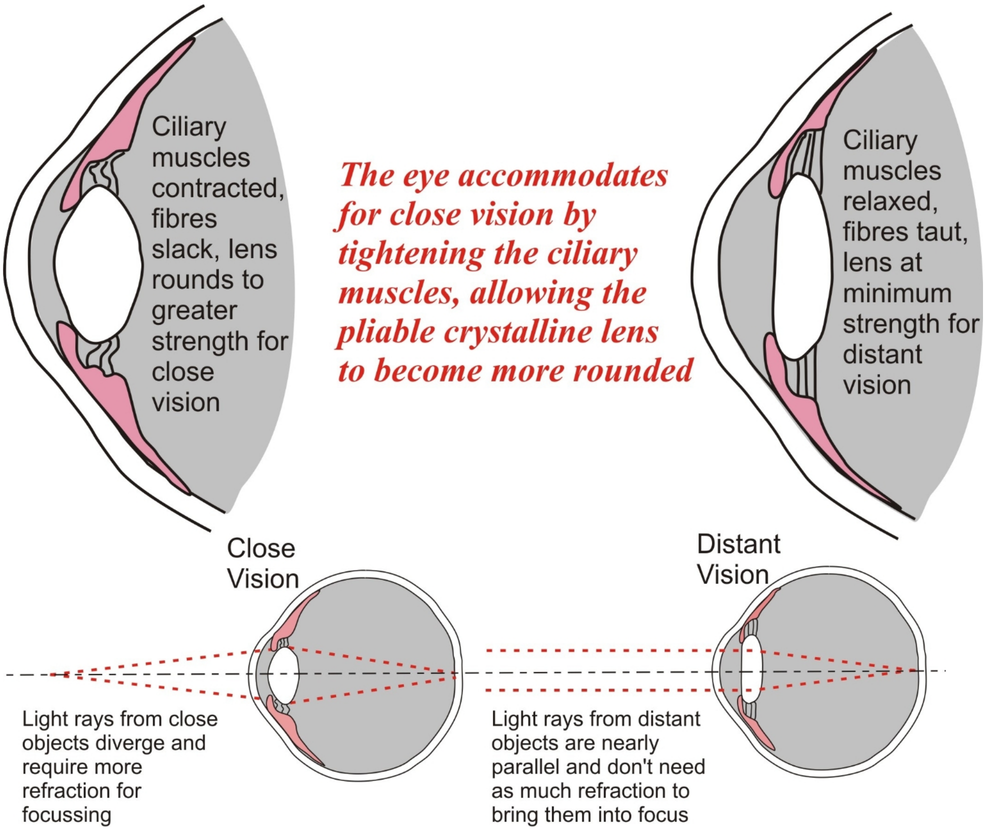


Figure 6.30

Accommodation

In order to see an object as clearly as possible, we need to concentrate the light rays onto the cones, and more specifically onto the fovea, where the concentration of cones is greatest. The acuteness and sharpness of our vision is termed visual acuity and is dependent on our ability to focus light on the retina. From Figure 6.30 it can be seen that in order to focus on a distant object, the lens must be elongated by the ciliary muscles. To focus on a near object, the ciliary muscles relax and the lens becomes rounder.

The arrangement of rods and cones is shown in Figure 6.31. The greatest concentration of cones is found at the fovea, and this corresponds to the position on the retina where visual acuity is at its best.

Cones are less sensitive to light than the rod cells in the retina (which support vision at low light levels), but allow the perception of colour. They are also able to perceive finer detail and more rapid changes in images, because their response times to stimuli are faster than those of rods.

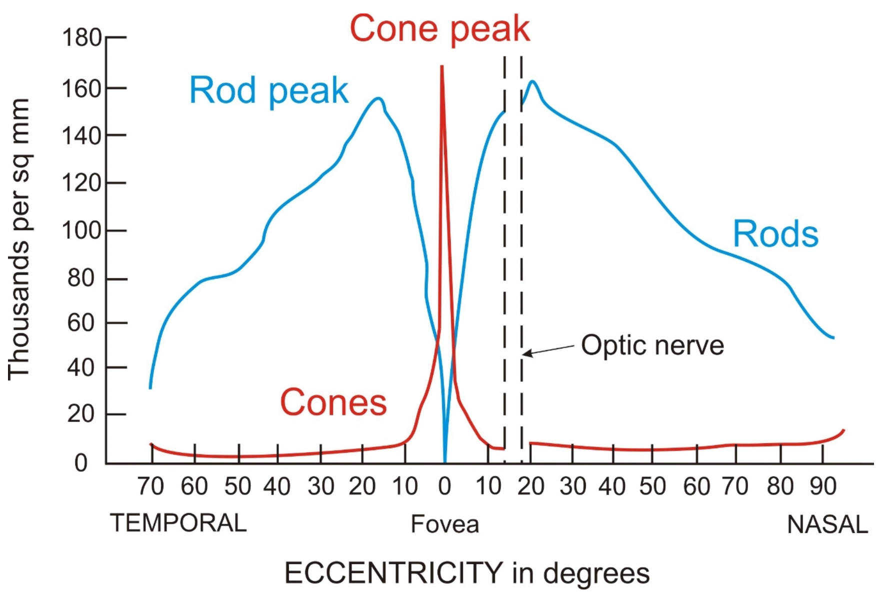


Figure 6.31

Cones and Rods in the Eye

You will remember from your Class 1 or 2 medical tests that your eyes were tested using what is known as a Snellen Chart (see Figure 6.32). The figures on the right , for example 20/20, indicate that the subject can see at 20 feet what a person with standard visual acuity can see at 20 feet. The metric equivalent is 6/6 vision where the distance is 6 metres. Twenty feet is essentially infinity from an optical perspective. For that reason, 20/20 vision can be considered nominal performance for human distance vision; 20/40 vision can be considered half that acuity for distance vision and 20/10 vision would be twice normal acuity. 20/20 is not regarded as the average acuity, the average is rather 20/15 or 20/10. Average acuity does not drop to 20/20 until the age of about 60 - 70 years.

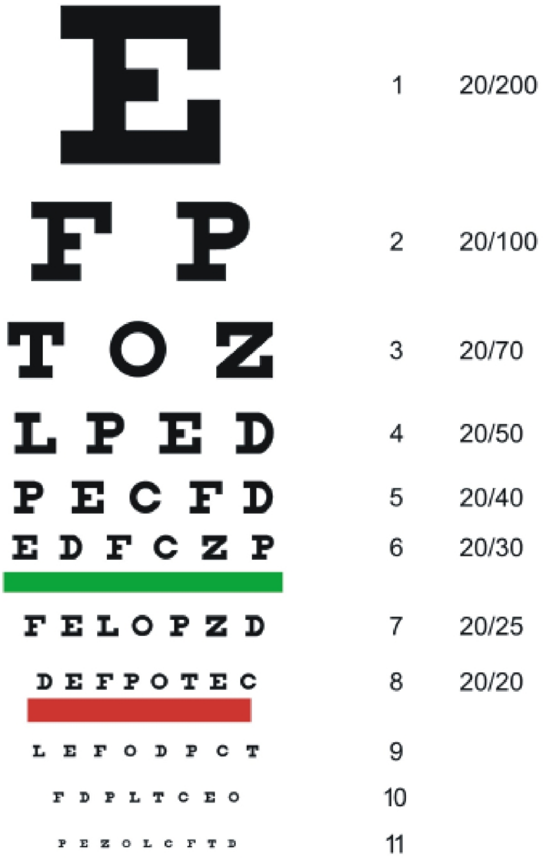


Figure 6.32

The Snellen Chart

Using cone vision will allow you to see colour and detail in bright light. If the light intensity reduces, the cones will try to adapt to the lower light levels. The word adaptation is used to describe this process of adapting to various levels of light and darkness.

The fovea is blind to dim light (due to fact that there are only cones) and the rods are more sensitive, so a dim star on a moonless night must be viewed from the side, so it stimulates the rods.

Two eyes are needed to give us binocular vision (as opposed to monocular - one eye). This allows for better focus as well as providing us with depth perception.

The blind spot can still be a problem if an object could only be only seen with one eye - the other eye being masked by a window frame, or even a spectacle frame, for example. Then the object would be invisible to the pilot if the focussed image fell onto the optic nerve. Figures 6.33 and 6.34 give you an opportunity to check this out for yourself.

With the right eye closed, focus on the dot on the right using your left eye (Figure 6.33). Move the page slowly towards and away from the eye. At some point (about 30 cm) the aircraft on the left will disappear. This is because the image of the right hand dot has fallen on the left eye's optical blind spot.

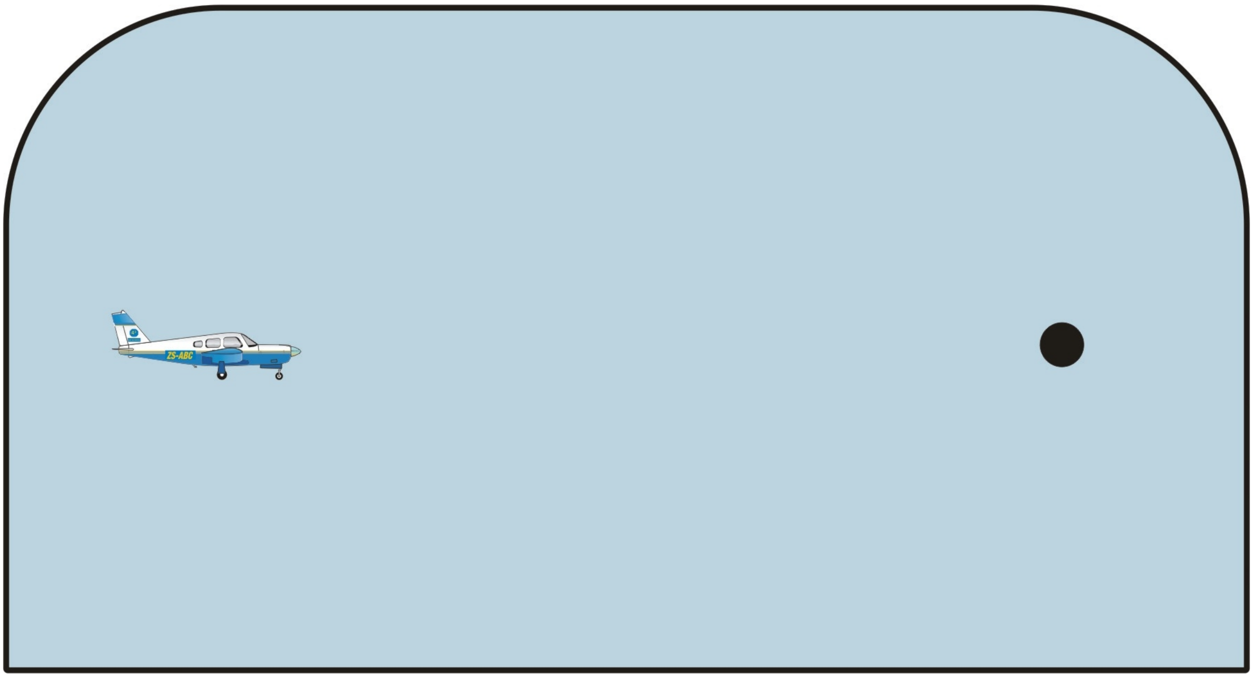


Figure 6.33

The optical blind spot

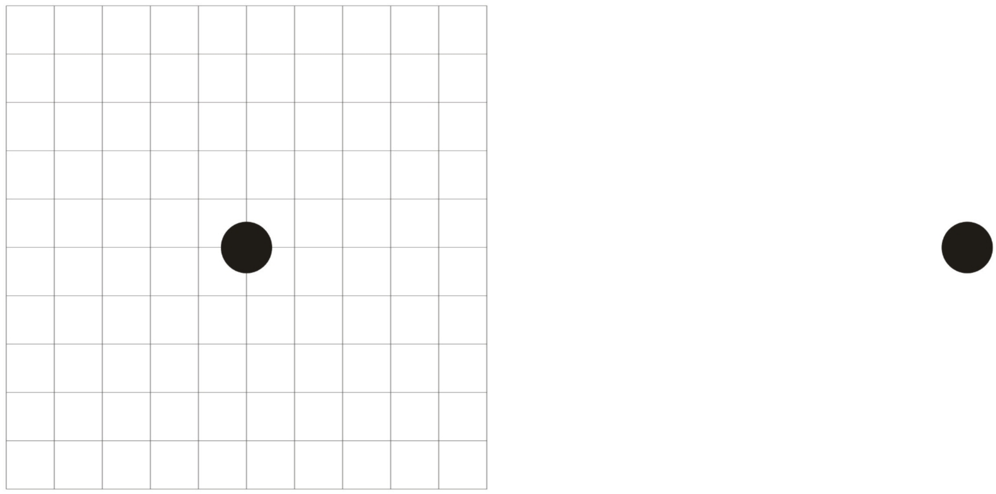


Figure 6.34

The blind spot

Using Figure 6.34, close the left eye and focus on the dot on the left (inside the grid) and by moving the page, the dot on the right will disappear. Now reverse the position. Close the right eye and focus on the right dot. You guessed it ..... the image of the right dot will disappear. What is unusual is that the square grid seems unaffected - you can still see the full grid. This is because the brain fills in the missing information, and the grid still seems to be visible. This just proves that we can be deceived into seeing what is not necessarily there. Seeing is NOT believing!

Adaptation

The eye takes approximately 20-30 minutes to fully adapt from bright sunlight to complete darkness and become ten thousand to one million times more sensitive than at full daylight (see Figure 6.35). In this process, the eye's perception of colour changes as well. However, it takes approximately five minutes for the eye to adapt to bright sunlight from darkness. This is due to cones obtaining more sensitivity when first entering the dark for the first five minutes but the rods take over after five or more minutes.

Rods and cones in the eye are used during dark adaptation. Rods are more sensitive to light and so take longer to fully adapt to the change in light. Rod adaptation can take up to a few hours to completely regenerate. Cones take approximately 9 minutes to adapt to the dark.

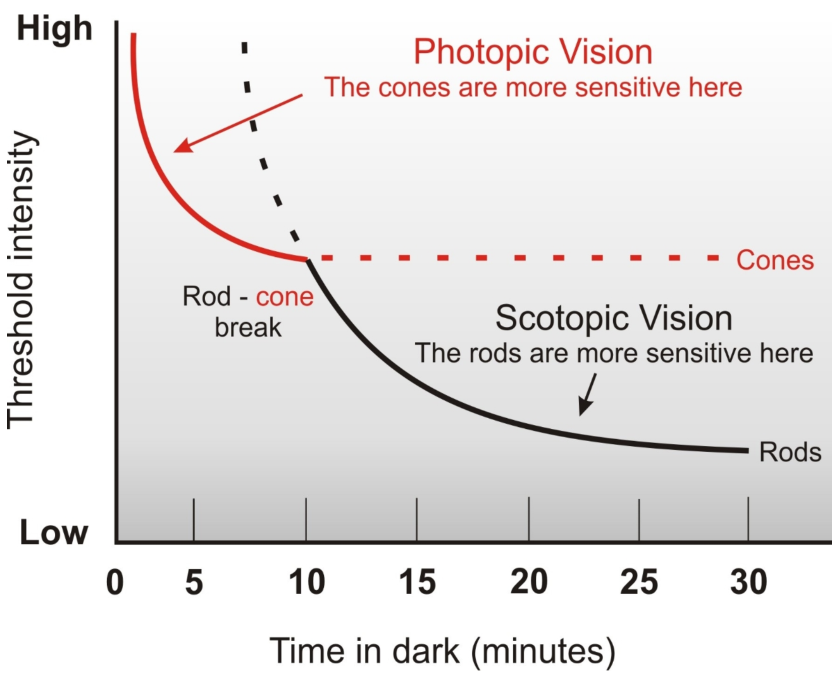


Figure 6.35

Adaptation

Daytime (or bright light conditions) when the cones are used is known as Photopic Vision, while the rods in dim light is known as Scotopic Vision.

It is important that when looking out during the day that you do not let your eyes settle for too long on one spot in space. Follow a set pattern of small sectors of the sky so that you can optimise cone vision. This will prevent the eyes from focussing on one particular item for too long. So scan the whole sky in a set pattern, allowing the eyes to re-focus on objects at varying distances, ie the horizon, clouds, the ground below, the instrument panel. At night the picture changes somewhat. Because the rods are used in low light situations, the periphery of the eye must be used (Figure 6.36).

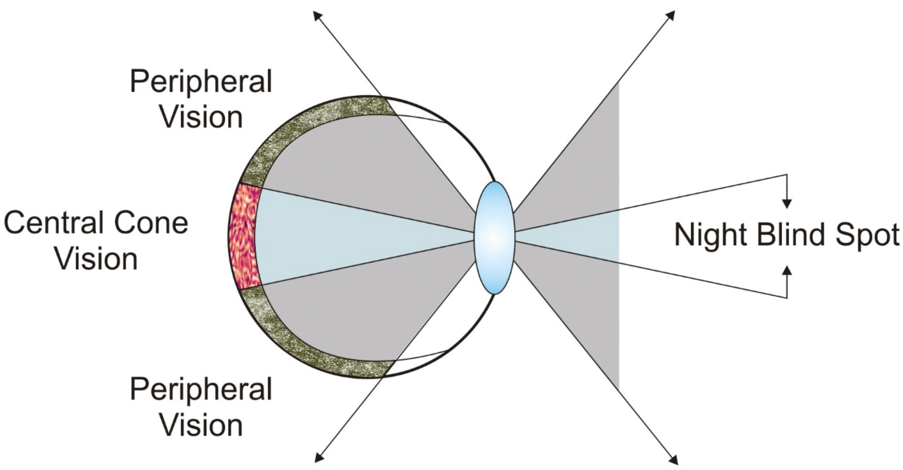


Figure 6.36

Limits of Vision

At night peripheral vision must be used as the area of the retina where the cones are concentrated becomes what is called “the night blind spot”. If you want to see an object at night, you should actually look to the side of it, and not directly at it. When scanning at night, this must be borne in mind, and a random scan pattern must be used.

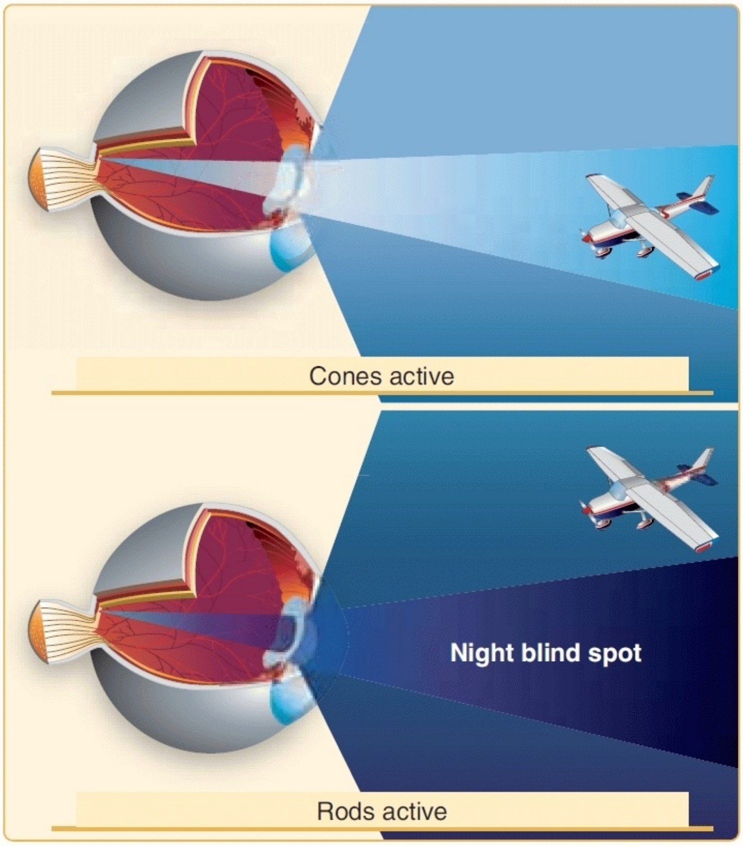


Figure 6.37

Night Blind Spot

Vision Defects

Vision defects at birth are usually ascribed to the shape of the cornea. The cornea allows for about 70% of our focussing ability, while the lens provides the remaining 30%. If the cornea is slightly flatter than normal, the eye is referred as being a short eyeball. If the cornea is more rounded, the eye is referred to being a long eyeball (see Figure 6.38).

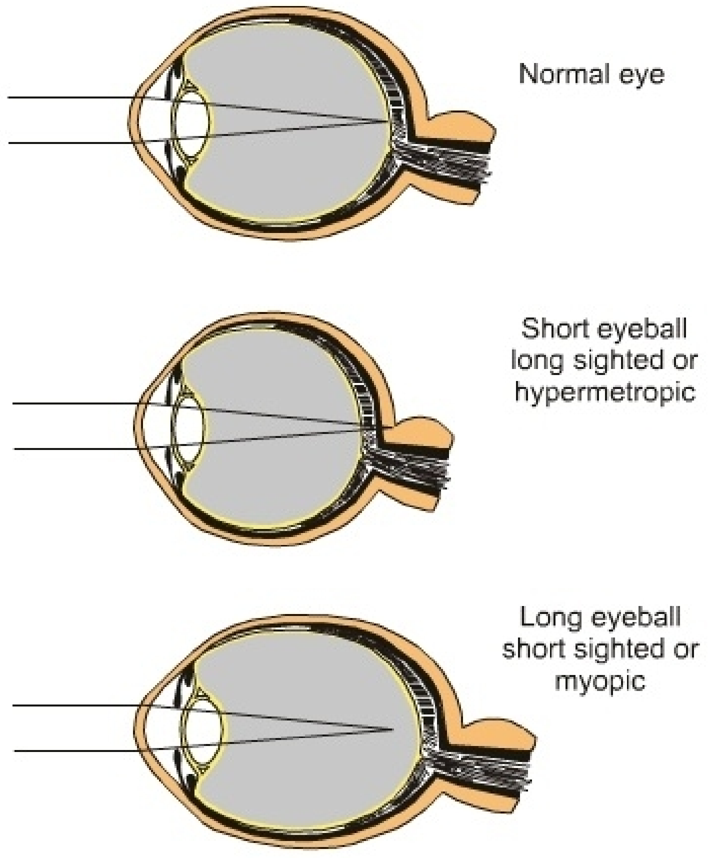


Figure 6.38

Eye Defects

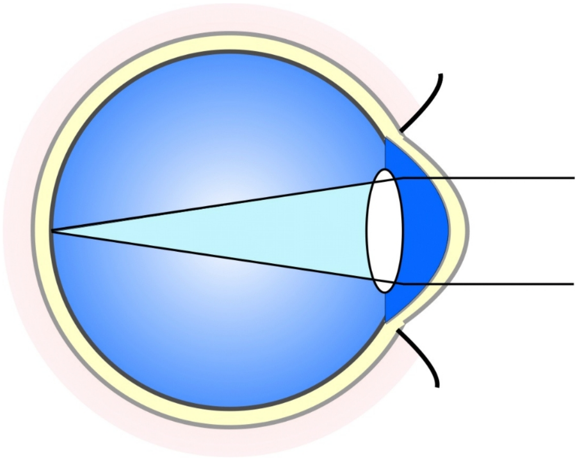


Figure 6.39

Normal Focus

Myopia (Shortsightedness). This is something you are born with and is a result of the image focussing short of the retina. The subject will have little difficulty in focussing on close objects (hence the name shortsightedness) but will have difficulty focussing on distant objects. This can be corrected by using a concave lens. A concave lens is also known as a minus lens.

Figure 6.40

Myopia and its correction

Hyperopia (Longsightedness). This is also an early eye defect which is the opposite of myopia. In this case the image focusses behind the retina and distant objects are seen with ease but close objects not. This can be corrected with a convex lens. A convex lens is also known as a plus lens.

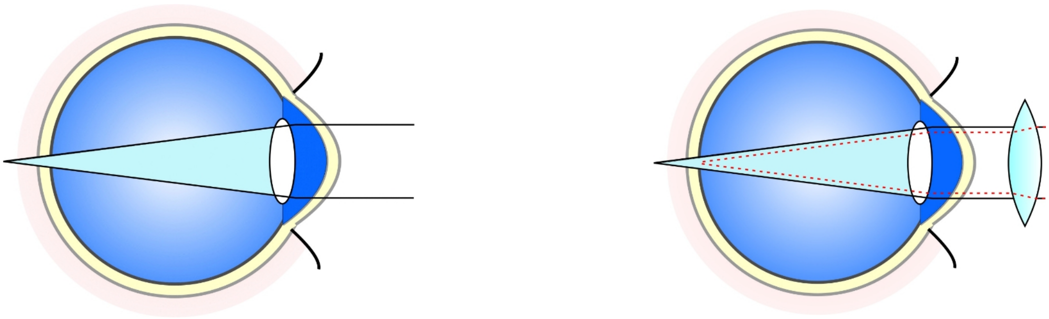


Figure 6.41

Hyperopia and its correction

Presbyopia. This is from the Greek words “presbus” old man and “ops” eye, literally “old man’s eye” which describes the condition to a tee. This is a condition which develops with age and occurs in people in their mid-forties. The eye loses some of its elasticity as it grows older and there is a difficulty in focussing on close objects. It is often joked that an older person’s arms aren’t long enough when, even holding reading material at arm’s length, they are not able to focus. This is a good sign that presbyopia is present, and other symptoms are blurred vision at normal reading distance, and eye fatigue and headaches when attempting to do close work. The condition will continue to deteriorate as one gets older, but it can be corrected in the same way as hyperopia with a convex lens. It cannot be prevented as it is a natural part of the ageing process. A good example of presbyopia is when you can see the TV, but you can’t see the remote!

There are other problems associated with the eye, which could cause problems. One is empty field myopia in which the subject has been staring at nothing for a while. When this happens the eyes will focus at a distance of about 2 metres ahead and anything further than that is not seen. When you see someone just staring at nothing in particular, you have to attract their attention by calling to them, they don't even see you waving at them! This condition can occur in flight when a pilot does not make use of a proper scan pattern and looks out at a cloudless sky for too long. A 747 could pass through his distant field of vision and he won't see a thing!

Other Ailments

Astigmatism. In the case of myopia and hypermetropia, it is the shape of the eyeball that leads to the problem. In a person with an astigmatic eye, the eye has an asymmetrical or irregular shape. The result is that there is not a single focus point on the retina. There could be several, or the focus point could be a line in either the horizontal or the vertical plane. Correction for astigmatism is achieved by using an asymmetrical lens or by surgery.

Cataracts. A cataract is a clouding that develops in the lens of the eye. This leads to an obstruction in the light passing through the lens. This can also be seen as a yellowing of the eye, and could lead to total blindness if left untreated. They can be surgically removed.

Colour Vision. As we grow older we will be exposed to more and more light. Ultra-violet and blue light from the sun will eventually affect the cornea. This will be in the form of a discolouration of the cornea itself, usually becoming yellow. This will result in yellow light being filtered out, and our colour vision will be affected. Colours that will fade will be yellows and reds.

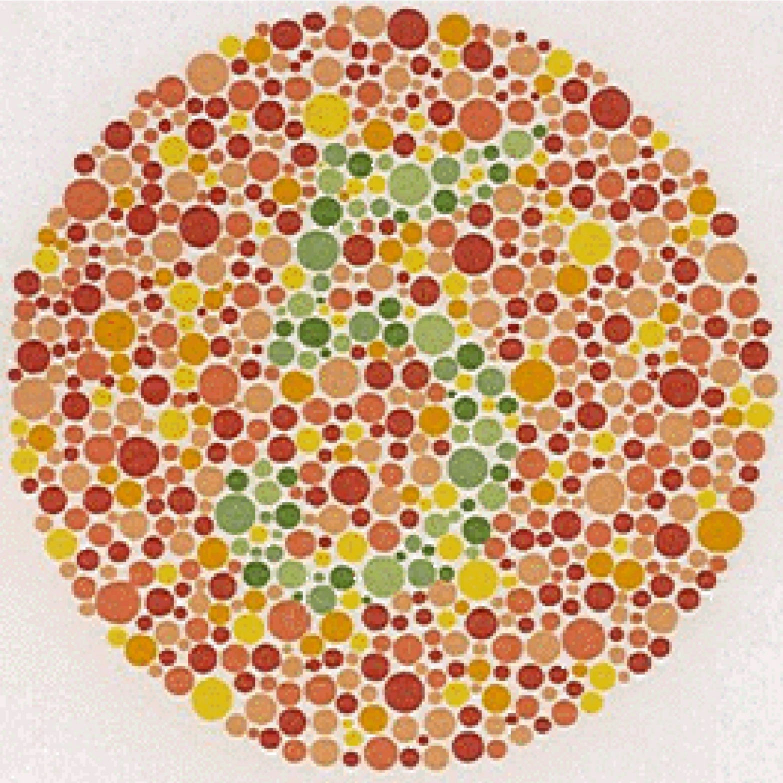


Figure 6.42

Colour Blindness Chart

Colour Blindness. This is not to be confused with colour blindness, which is the inability to differentiate between colours (see Figure 6.42). This is usually genetic, but can occur as a result of eye, nerve or brain damage, as well as exposure to certain chemicals. It is obvious that a person who cannot differentiate between red and green cannot be allowed into a cockpit to fly.

Some pilots who can see perfectly during the day may not be able to see all that well at night. The term “night blindness” is used but is really night myopia. The subject is usually unaware of the problem because of the good day vision. The cause is the different colour frequencies at night, and although the person can focus on a near object quite easily, distant objects are not seen even though an effort is being made to see them. Hypoxia will aggravate this condition, as will smoking.

Optical Illusions

Even when our eyes are working perfectly, they may play tricks on us. Things aren’t always what they appear to be. The brain sometimes interprets things differently to the way they actually are. A visual illusion occurs when our brain’s interpretation of an image differs from reality. Figure 6.43 shows some common illusions.

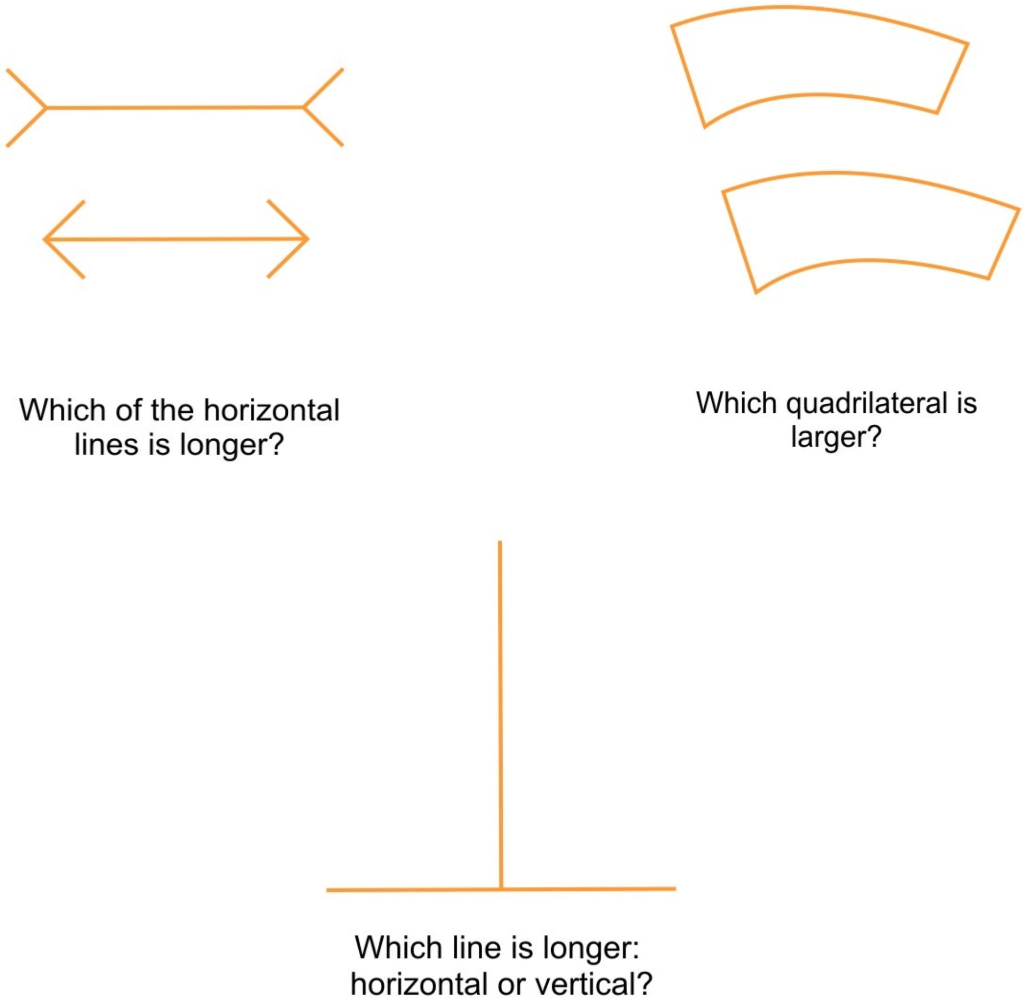


Figure 6.43

Optical Illusions

Both lines are the same length. It is the additional visual information which makes it appear that the top one is longer. The quadrilaterals are the same size, but the bottom one is not placed directly below the top one, making it appear the larger of the two. The lines in the bottom image are the same length, but the vertical seems to be the longer of the two. Visual information in the vertical can be misleading.

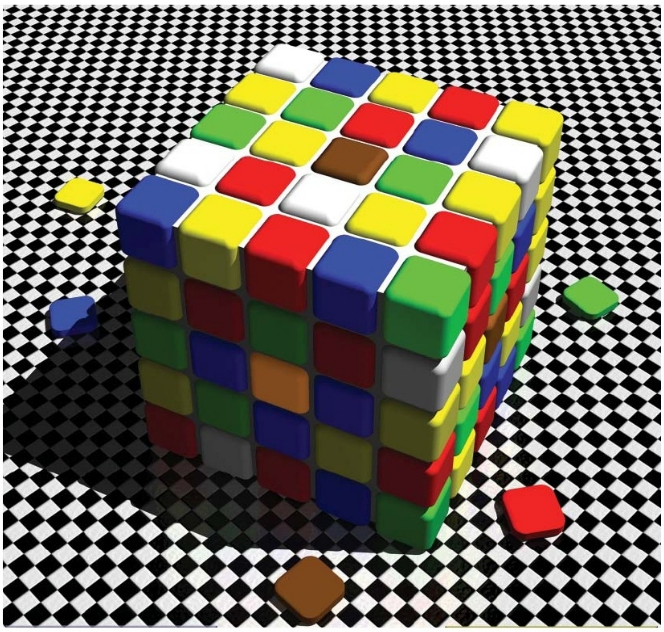


Figure 6.44a

Visual Illusion - Colour

Not only do shapes and lines appear to be different, but even colours may appear to be very different to what they are in reality. In the cube shown in Figure 6.44a, the dark cube in the middle of the top face appears to be a dark brown colour, while the one in the middle of the front face seems to be orange. They are exactly the same colour. Once again it is the background information that makes us see what we want to see.

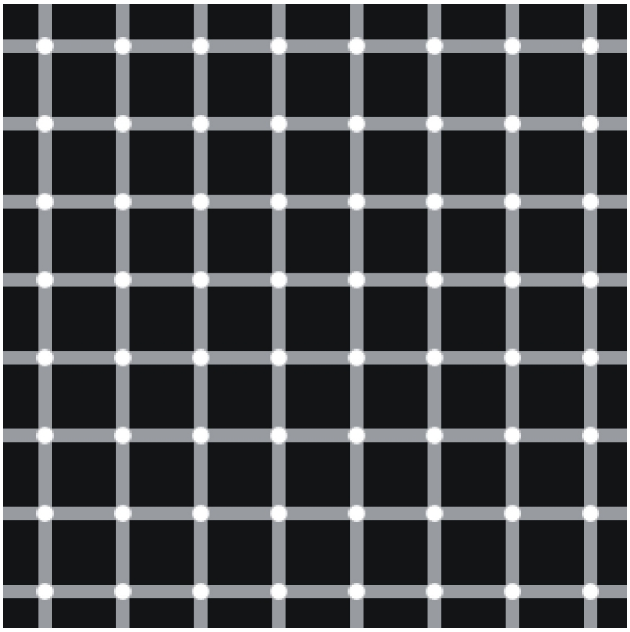
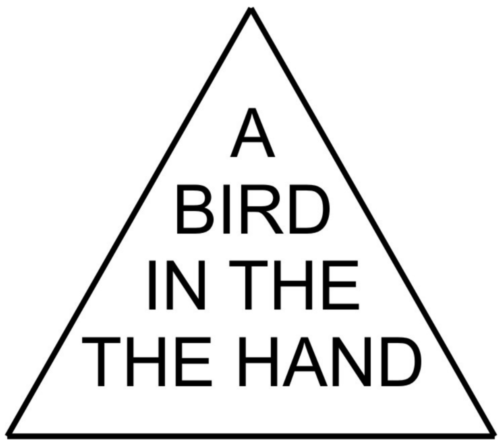


Figure 6.44b

Grid Illusion

In Figure 6.44b, known as the scintillating grid illusion, shape, position, colour, and 3D contrast converge to produce the illusion of black dots at the intersections.

Visual illusions can play tricks in simple print. Read the words in the triangle out loud to yourself:



Some times the brain can delete some of the
the visual information. How many “the” did you
you see in the triangle before you read this question?

Now read the above sentence above more carefully....

Some times the brain can delete some of the
the visual information. How many “the” did you
you see in the triangle before you read this question?

“The” appeared twice in the triangle. Twice in the next sentence, and “you” twice in the sentence.

Runway Illusions

Various terrain features and atmospheric conditions can create optical illusions. These illusions are primarily associated with landing. It is imperative that pilot's are aware of the potential problems associated with these illusions, and take appropriate corrective action. They become more of a problem when you are transitioning from instrument flight to the final visual approach.

When a runway illusion is created, there are only two options open - either you climb, or you descend. If you believe you are too far away from the runway, you cannot project yourself forward, but you can go lower. This has the effect of shortening the visual distance to the runway, making it appear to be closer, and therefore solving the problem. Wrong. If you go lower on the final approach you are in danger of landing short.

On the other hand, if the illusion is created that you are too close, you cannot project yourself backwards, so you climb, lengthening the visual distance. This appears to have solved the problem, but being high means that you have to lose more height in the same time during the approach, so rate of descent is increased. This could result in damage to the undercarriage if the round-out is not properly controlled, or lead to a deep landing. This could result in the aircraft running out of stopping distance. Figure 6.45 shows the two conditions.

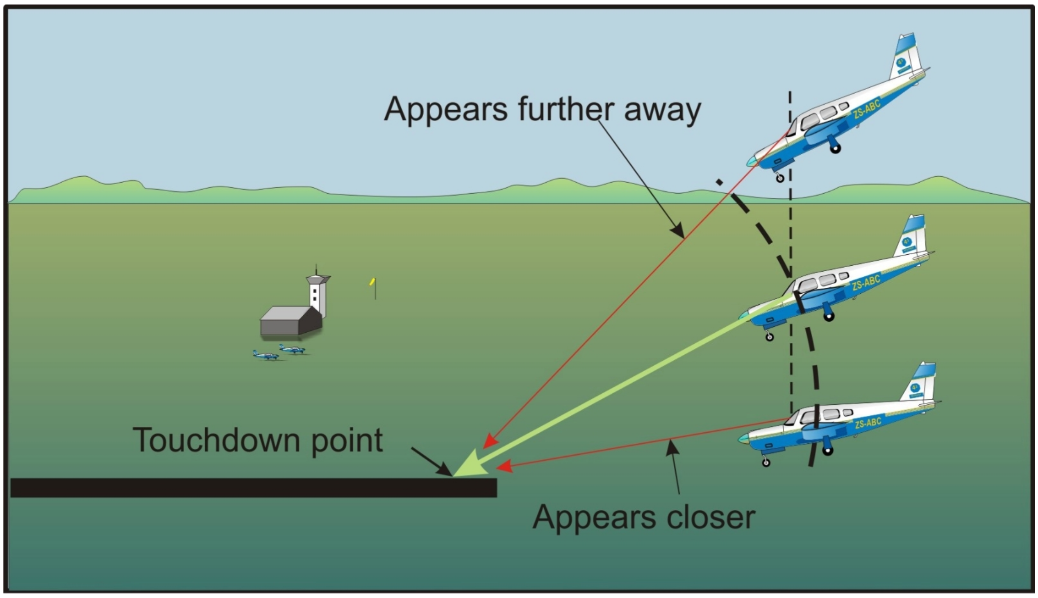


Figure 6.45

Effect of Changing Height on Visual Distance

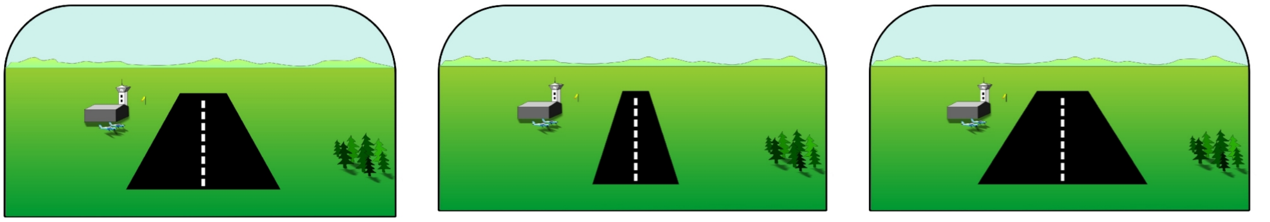
Runway Width Illusion

A narrower-than-usual runway can create an illusion the aircraft is at a higher altitude than it actually is, especially when runway length-to-width relationships are comparable (Figure 6.46). The pilot who does not recognize this illusion will fly a lower approach, with the risk of striking objects along the approach path or landing short. A wider-than-usual runway can have the opposite effect, with the risk of the pilot levelling out the aircraft high and landing hard, or overshooting the runway.

The same rule may be applied to a runway that is longer or shorter than the one you may have become used to.

Runway and Terrain Slopes Illusion

An upsloping runway, upsloping terrain, or both, can create an illusion that the aircraft is at a higher altitude than it actually is (Figures 6.47 and 6.48). The pilot who does not recognize this illusion will fly a lower approach. Downsloping runways and downsloping approach terrain can have the opposite effect.

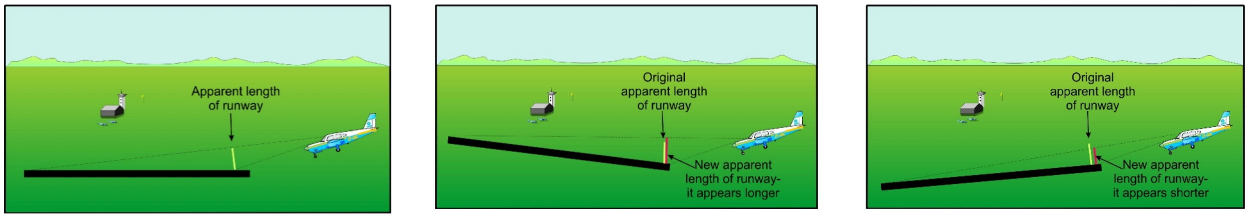


a b c

Figure 6.46

Effect of Narrow or Wide Runway

The image on the left (a) shows the "normal" width. The runway in the middle (b) is narrower than usual, creating the illusion that it is further away, or that you are too high. The tendency will be to go lower. In the image on the right (c), a wider runway, the illusion is that you are too low or too close, so the tendency will be to climb.

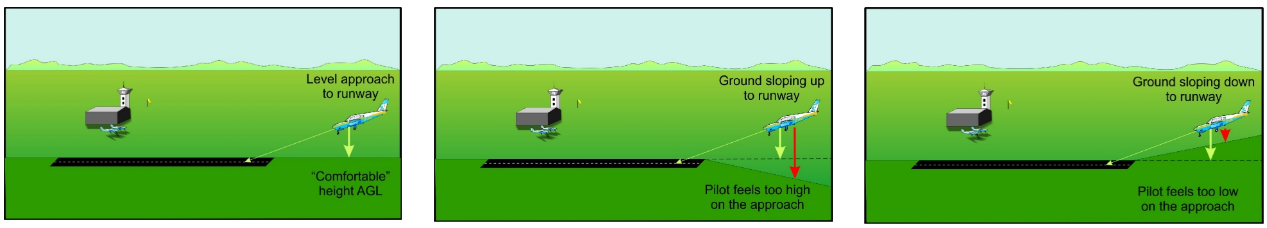


a b c

Figure 6.47

Effect of Sloping Runway

The image on the left (a) shows the "normal" level runway. The runway in the middle (b) is sloping upwards, more apparent length is seen, and the illusion is that you are high. The tendency will be to go lower. In the image on the right (c), a runway sloping down, the illusion is that you are too low, so the tendency will be to climb.



a b c

Figure 6.48

Effect of Sloping Terrain

The image on the left (a) shows level terrain on the approach. The runway in the middle (b) has terrain sloping downwards on the approach. The ground therefore appears further than usual creating the illusion that the aircraft is higher than usual. The tendency will be to go lower. In the image on the right (c), the terrain is sloping upwards on the approach, creating the illusion that the ground is closer, therefore the aircraft is low. The tendency will be to climb.

Featureless Terrain Illusion

An absence of surrounding ground features, as in an over-water approach, over darkened areas, or terrain made featureless by snow, can create an illusion the aircraft is at a higher altitude than it actually is. This illusion, sometimes referred to as the "black hole approach," causes pilots to fly a lower approach than is desired.

Water Refraction

Rain on the windscreen can create an illusion of being at a higher altitude due to the horizon appearing lower than it is. This can result in the pilot flying a lower approach.

Haze

Atmospheric haze can create an illusion of being at a greater distance and height from the runway. As a result, the pilot will have a tendency to be low on the approach. Conversely, extremely clear air (clear bright conditions of a high attitude airport) can give the pilot the illusion of being closer than he or she actually is, resulting in a high approach, which may result in an overshoot or go around. The diffusion of light due to water particles on the windshield can adversely affect depth perception. The lights and terrain features normally used to gauge height during landing become less effective for the pilot.

Fog

Flying into fog can create an illusion of pitching up. Pilots who do not recognize this illusion will often steepen the approach quite abruptly.

Autokinesis

Autokinesis, also known as the autokinetic phenomenon, is a visual illusion. It can occur under certain conditions, especially on dark nights in areas with few visual cues (such as lights or other illuminated objects or landmarks). When a small, dim, and fixed light source remains within visual range for an extended period of time, this phenomenon can occur, making it appear as if the light source were moving. This visual illusion can be of particular danger to pilots at night. In addition, it is possible that this illusion may account for some supposed UFO sightings in which witnesses may see an isolated light, such as a bright star or planet, seeming to move erratically around.

A stationary light stared at for 6 to 12 seconds in the dark will appear to move. This phenomenon can cause considerable confusion for pilots, especially those flying in formation or rejoining on a refuelling tanker at night, so it should not be of too much concern for the private pilot!

In the event of there being a possibility that you may find yourself confronted with the problem, or in order to prevent it, you should:

a. Shift your gaze frequently to avoid prolonged fixation on light sources.

b. Attempt to view an object with a reference to stationary structures or landmarks.

c. Make eye, head, and body movements to eliminate the illusion.

d. Monitor the flight instruments to prevent or resolve any perceptual conflict.

Spatial Disorientation

In order to determine our position, attitude or motion relative to the earth's surface and true vertical, we need to rely on our eyes, balance organs, and muscles. Forces acting on our muscles, skin or joints stimulate receptors and give us an idea of what is going on. This is sometimes referred to as "seat of the pants" feel. This is called our Spatial Orientation. Take away one or more of the senses, and we can very quickly become disorientated.

Eyes. Vision is the most important contributor to orientation. From what we can see, we are able to determine our body's position, attitude and any motion relative to visible objects. Even if external references are removed, for example, when flying in cloud, our eyes are still able to use the information provided by the instruments to keep us orientated.

Balance Organs. If we find ourselves in a position where we are unable to see, there are still our balance organs in the inner ear, and the receptors in the skin, muscles and joints to give us sufficient information to stay upright, even in a very dark room.

This is all very well if we are subjected to 1G when standing on the ground. In the air, when the body is subjected to motion which is not normal on the ground, these systems may supply incorrect information to the brain, and disorientation can occur.

There are several reasons why it is far more difficult to maintain the correct spatial orientation when flying than is the case on the ground. These are:

a. Angular (changes in direction) and linear (changes in speed) motion differ in intensity and duration from that to which we are accustomed and fully adapted.

b. An aircraft operates and has to be controlled in 6 degrees of freedom (3 linear and 3 angular), while on the ground we have usually only operate in 5 degrees of freedom and we remain in contact with a stable reference, the earth. The degree of freedom missing on the ground is vertical acceleration.

c. In the air, external visual cues may be very difficult to interpret. An example is a cloud base above you which is crossing your path at about 40-50°. It appears to be slanted upwards on one side, and if the actual horizon is not visible or indistinct, it can be very confusing and lead you into believing a false horizon. Another problem that you have with visual cues is the size and shape of objects. Take trees for example. You get used to seeing trees on short finals, and you eventually start judging your height by the appearance of the trees which you quickly get used to. Then you find yourself at an unfamiliar aerodrome, with different sized trees, and your judgement is affected.

d. Unless you are properly trained to use them, instrument indications may be incorrectly interpreted, or you concentrate on the wrong indications. This has led to many accidents in the past, and, sadly, will lead to many more in the future. Never put yourself in a position where you are not totally in control.

False sensations or perceptions are a very real part of flying, and they show us how limited our senses really are. If you have been trained to use the instrument panel in the correct way (ie you have an instrument rating) then you will be aware of these false sensations, and you will be able to overcome them. Things become very dangerous when you are not aware that your sensations are incorrect and you base your control of the aircraft on false perceptions. You will no longer be fully in control, or may lose control completely, and flight safety is jeopardized.

Avoidance of Disorientation

The best advice anyone can give you about avoiding disorientation, is avoid conditions where it is possible. Knowledge of the causes of spatial disorientation and the flight conditions where it is most likely to occur will lead to avoidance of those flight conditions. Do not put yourself into a situation where you have to rely on your senses to save the situation - you will more than likely be the loser. Do not fly in cloud or poor visibility. And remember that poor visibility can occur when flying in haze, dust and poor light conditions. Stick to the rules and you should be safe from spatial disorientation.

If you have to fly in any of the above conditions, only do so if you are proficient at instrument flying. Even if you have an instrument rating, it is no guarantee that you will be safe. You have to be in current practice, and must be very conversant with the aircraft and the relevant instrument procedures. Even an instrument rated pilot who has been out of practice for just a few weeks will require supervised refresher training.

You have to convince yourself that there is no such thing as flying by the "seat of your pants", and you must never base the control of the aircraft at any time on "seat of the pants" sensations, even if visual cues are lost for only short period of time. The prevention of disorientation can be summed up as:

PREVENTION IS BETTER THAN CURE, AND EXPERIENCE DOES NOT MAKE YOU IMMUNE.

Hearing

It is essential that pilots have a good standard of hearing. The ability to recognize all the sounds that one hears when flying is important to the safe completion of a flight. A pilot must hear, not just listen. Many radio transmissions, for example, will be masked to a certain extent by background noise. The pilot must hear what needs to be heard, and not merely listen to the noise. A very simple definition of noise is unwanted sound.

We hear because of sound waves which create pressure on the ear are converted to nerve impulses which then go to the brain. This process is best understood with the aid of a sketch (see Figure 6.49).

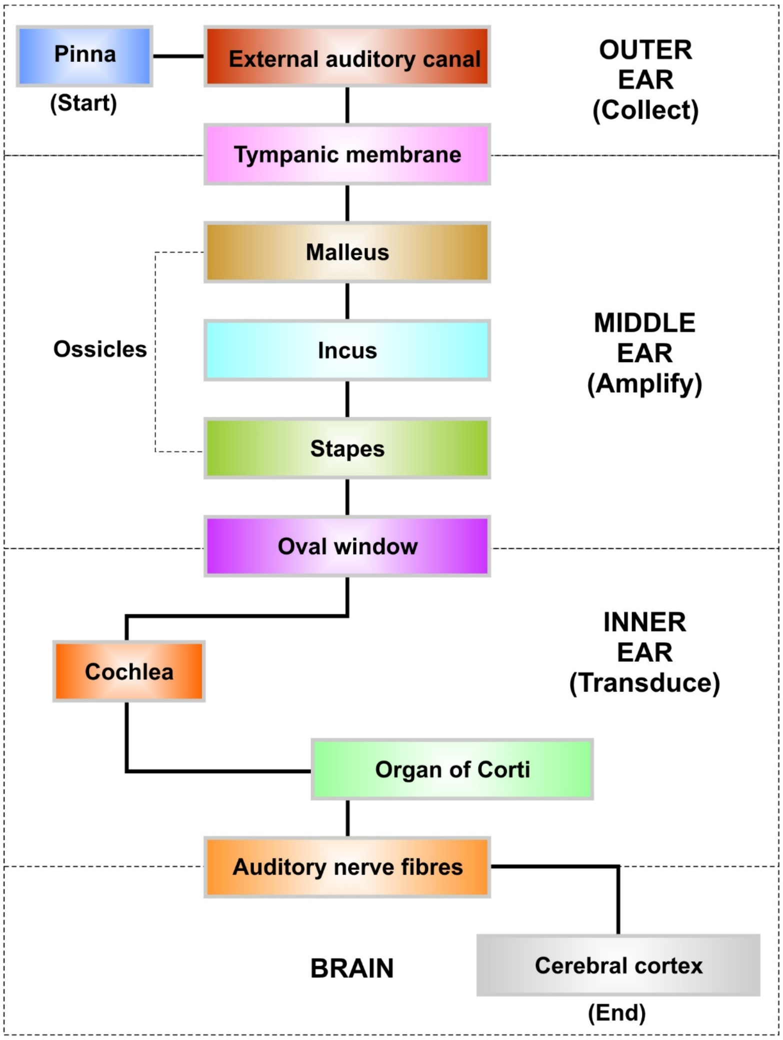


Figure 6.49

The Hearing Pathway

In Figure 6.50 the structure of the ear is shown. The ear is divided into three main parts, the outer ear, the middle ear and the inner ear. All three parts of the ear contribute to our hearing, while the inner ear also contributes to our balance via the vestibular apparatus. This consists of the semicircular canals and the otolith organs.

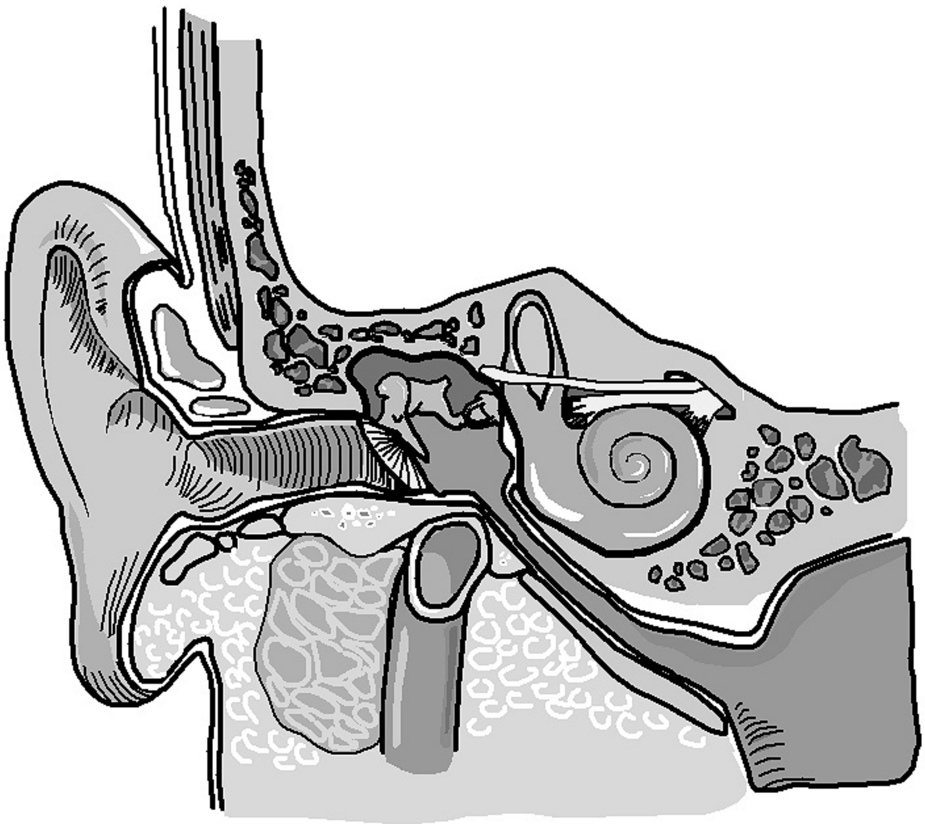


Figure 6.50

The Human Ear

The Outer Ear

The outer ear consists of the external ear flap or pinna (1) and extends inwards through the ear canal (2) to the eardrum (3). The eardrum, or tympanic membrane, divides the outer ear from the middle ear. This is the start of the hearing process where sound waves are collected by the pinna, and then channelled down the ear canal to the eardrum. The sound waves cause a vibration of the eardrum, and this is the first part of what is known as the hearing pathway (Figure 6.49).

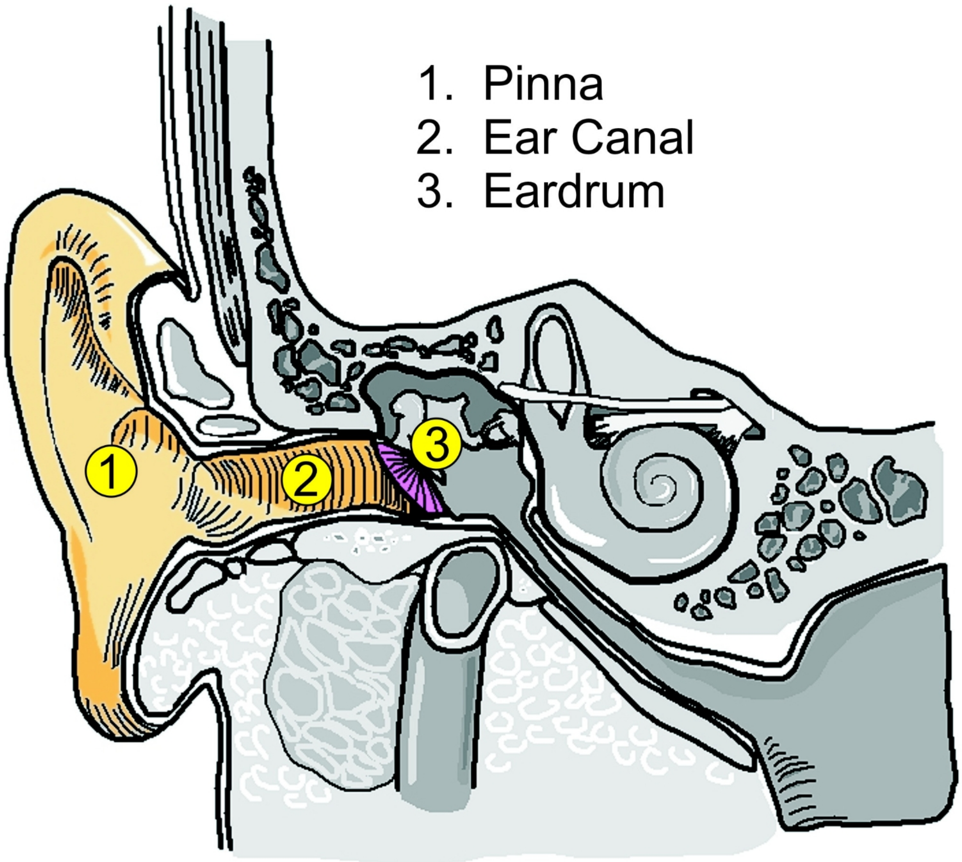


Figure 6.51

The Outer Ear

The Middle Ear

In the middle ear we find the ossicles. This which is the collective name for the three small bones attached to the inside of the eardrum. These are sometimes referred to as the hammer (4), anvil (5) and stirrup (6) because of their vague resemblance to the three items mentioned. The Latin names are sometimes used, and these are the malleus, the incus and the stapes. Their purpose is to amplify the sound waves first detected by the eardrum.

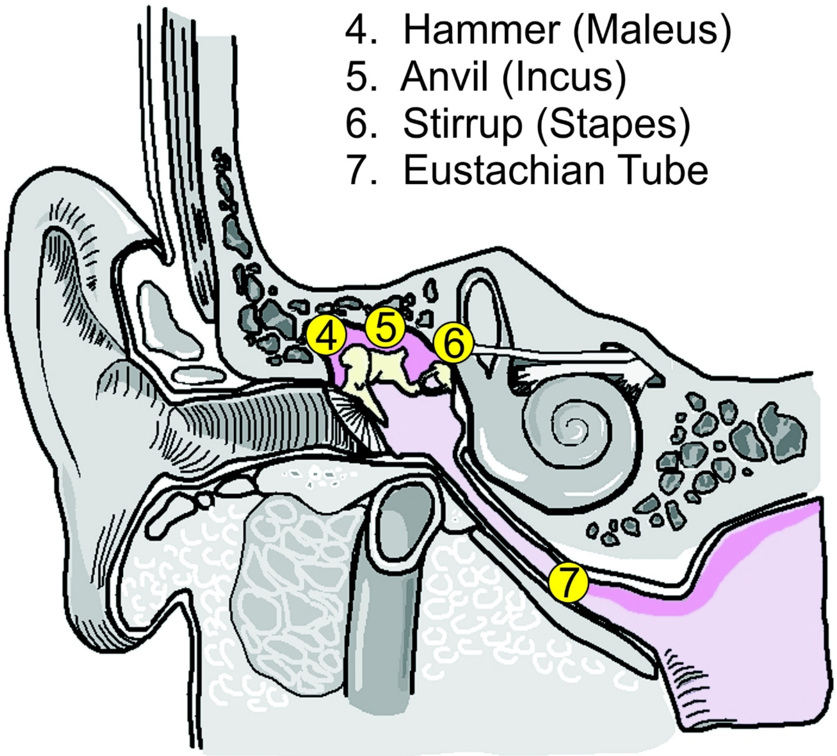


Figure 6.52

The Middle Ear

The middle ear is an air-filled cavity linking to the nose and throat via the Eustachian tube (7). The purpose of the Eustachian tube is to allow for a balancing of the pressure on either side of the eardrum. If the pressure on either side is equal, then the eardrum will respond to very slight changes in pressure from sound waves, making it a more efficient system.

A pressure imbalance, due to head cold for example, when the Eustachian tube is blocked, will result in a degradation of your hearing.

The Inner Ear

We then move to the inner ear where we find the cochlea (9). This is connected to the brain via the auditory nerve (10). Also in the inner ear is the vestibular apparatus (8) consisting of the semi-circular canals and the otoliths. These are the balance organs of the body and they sense motion in the angular, or rotational planes (semi-circular canals), and in the linear planes (horizontal and vertical acceleration).

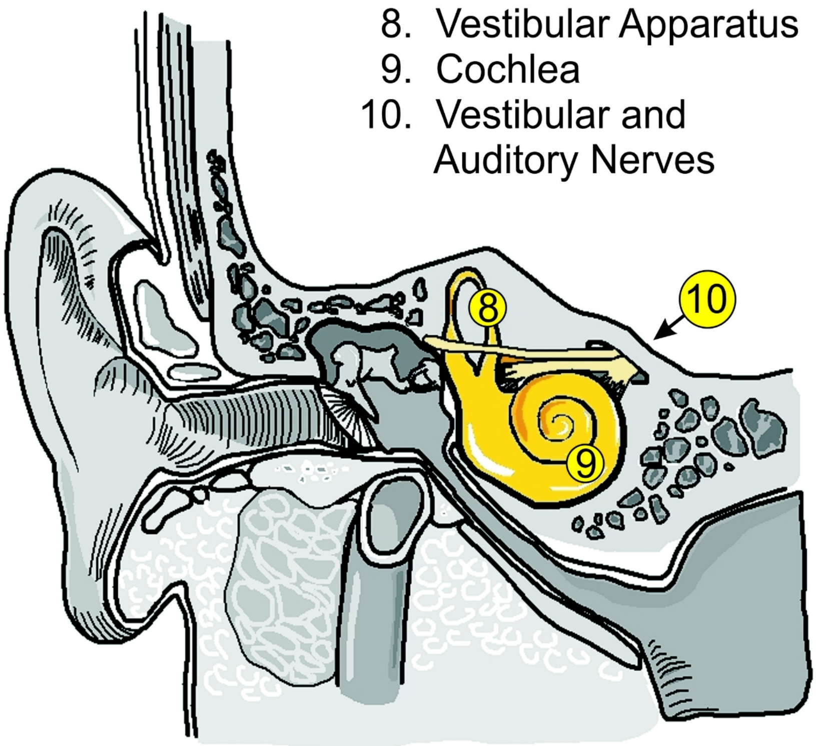


Figure 6.53

The Inner Ear

Hearing depends on two basic processes:

a. First there is the conductive system. We have the outer ear which collects sound waves. These are then directed to the eardrum which vibrates. This in turn transfers the vibrations to the ossicles which then transmit the vibrations to the cochlea.

b. The cochlea is the transducer system, meaning that it converts the vibrations, or sound energy, into a nerve impulse to the brain.

Any interference with the conductive system will lead to a form of deafness known as “conductive” deafness. This interference could occur at any stage in life due to damage to the middle ear from infection or a burst eardrum. This type of damage is often treatable with medication or surgery. A temporary hearing loss can also occur when there is a pressure difference between the middle and outer ear, as may be the case when descending from altitude with a head cold. A common cold or ear infection can cause the Eustachian tube to become blocked, and this will prevent the sound vibrations from transferring to the cochlea. Worse still, a blocked Eustachian tube may result in a rupture of the eardrum.

A problem which is more serious as far as a pilot is concerned, is damage to the sound-receiving system, the cochlea. This is irreversible in most cases, and is caused by overstimulation due to loud noise. A loss of hearing due to this is called Noise Induced Hearing Loss (NIHL). This damage may be temporary at first, for example, the deafness we experience when a loud report such as a gunshot goes off close to the ear. If we subject ourselves to excessive loud noise, this could lead to permanent damage and hearing loss. Because we become accustomed to the loud noise, we no longer react in the same way as we did to the first exposure.

This is where decibels come in. Sound intensity is generally measured in decibels (dB). 0 dB is the bottom end of the scale and would be found in a sound-proofed room such as a recording studio.

Jet aircraft, 50 m away	140	Kerbside of busy road, 5 m	80
Threshold of pain	130	Conversational speech, 1 m	60
Threshold of discomfort	120	Average home	50
Piston engine, a few feet away	120	Quiet bedroom at night	30
Chainsaw, 1 m distance	110	Rustling leaves in the distance	10
Disco, 1 m from speaker	100	Hearing threshold	0

All the aircraft which you will be flying are noisy places to be. In a light twin the average person may suffer significant hearing loss if he/she flies more than 8 hours per week. After 10 years you can expect to lose hearing sufficiently enough to have trouble understanding speech. In a light single this can happen with 5 hours per week, because you are closer to the source of the noise, making the intensity higher.

The message is that some form of protection must be worn. It has been determined that being subjected to a noise intensity greater than 85 dB will cause damage. Earphones with muffs offer some protection, but as with anything you buy, there are cheap ones, and there are good ones. If your earphones offer an impedance of only 20 dB and you are in an environment with a noise intensity of 120 dB, then your ears are being subjected to 100 dB - clearly too much. In such a case, earplugs must be worn as well as the earphones/earmuffs. Above 140 dB the two together will not be sufficient, and the time that you are exposed to the noise must be reduced.

Exposure to noise intensities of over 120 dB for just few hours per day for 3 to 6 months can cause deafness. Despite all of this, we still find people going to discos so that they can “feel the vibe”. When you can feel sound it is causing you to go deaf! And the bad news is that you can’t reverse the process. Wearing a hearing aid simply amplifies the background noise as well, so they are not permitted on the flight deck.

As far as the law (SA-CATS-MR 67.00.2) is concerned, pilots with a private pilot, or student pilot licence (requiring a Class 2 medical) must have routine audiometry. Applicants must not have a hearing loss in excess of 35 dB at each frequency between 500 and 2000 Hz, or 50 dB at 3000 Hz, in either ear. Applicants failing to comply with this standard in either ear may be assessed fit if the hearing loss for both ears, when averaged at each frequency, does not exceed the stated limit, and the applicant achieves 90 percent or better discrimination when speech audiometry is tested.

If the hearing loss is greater than the limits indicated an applicant still demonstrating a safe functional hearing ability in the presence of background flight deck noise may be declared fit. In cases such as these practical testing should be conducted by instructors of the Commissioner for Civil Aviation in an operational environment. In the event of further deterioration in the hearing ability this testing should be repeated.

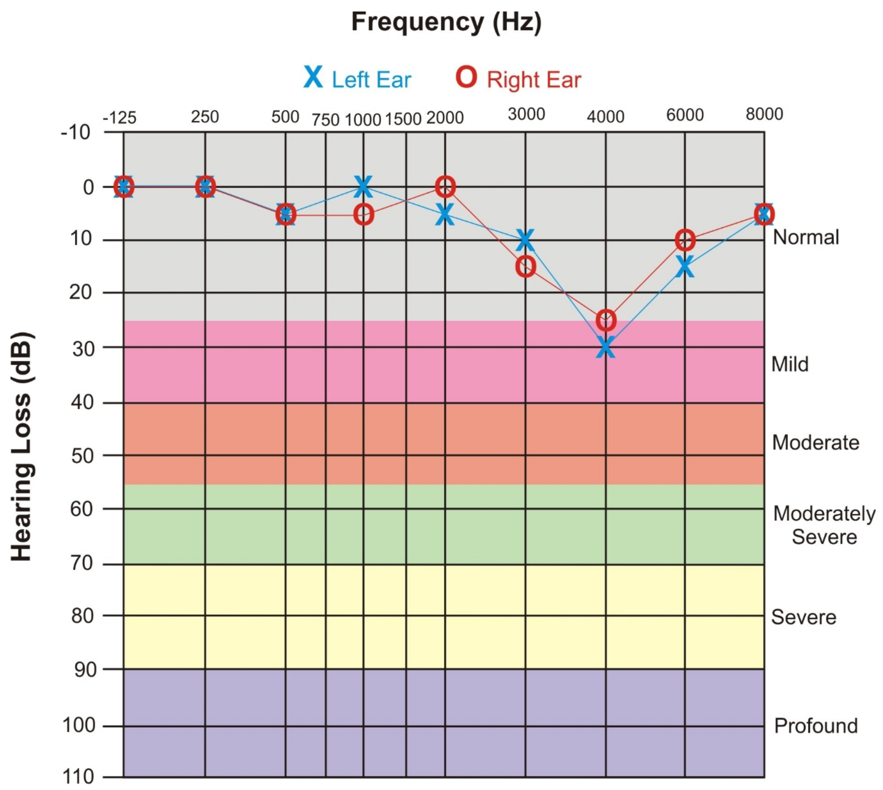


Figure 6.54

Acceptable Audiogram

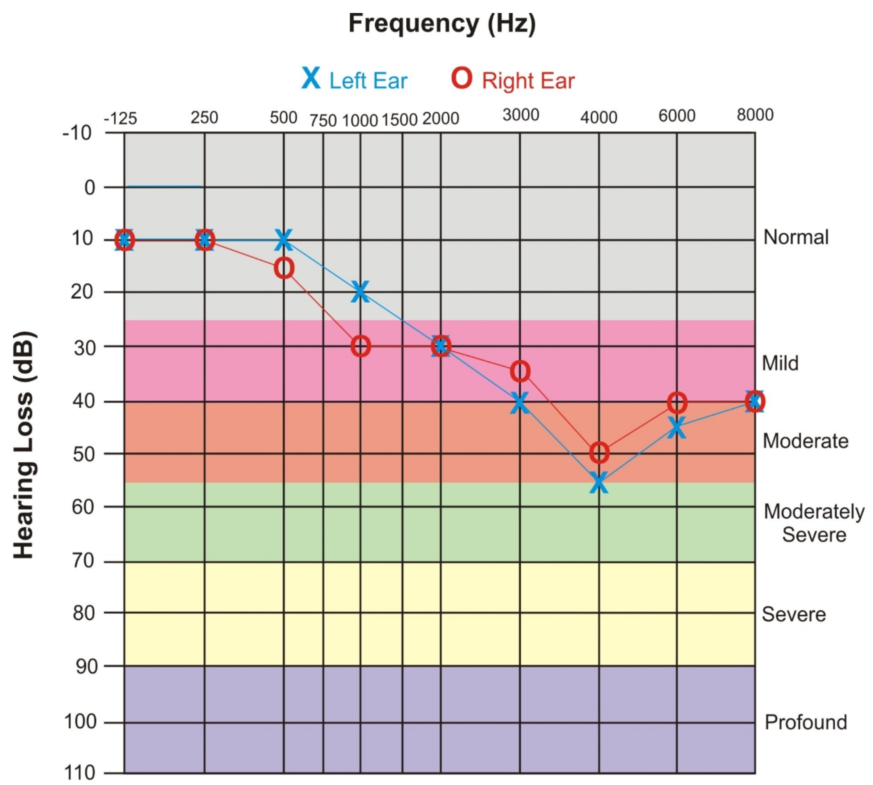


Figure 6.55

Unacceptable Audiogram

It is in your own best interests to ensure that adequate ear protection is worn AT ALL TIMES when in or near aircraft. your ears are most sensitive to sounds between 750 Hz and 3 000 Hz, although the average person has limits of between 20 Hz and 10000 Hz (some even have a greater range). The higher the frequency, the greater the risk of damage. Intense sounds or noise can induce temporary hearing loss and produce ringing in the ears when the noise ceases although recovery from this is fairly rapid. The extent of temporary loss is related to the frequency of the sounds, their intensity and duration. In temporary hearing loss the reduction of sensitivity is at frequencies higher than those of the stimulating noise.

A noise at one intensity will produce the same temporary loss of hearing as another noise at double the intensity if the duration of the former sound is double that of the latter. Noise-induced loss is not normally induced by sounds below 90 dB. If noise levels that induce temporary loss are experienced regularly over a period of years, then permanent loss of hearing is likely. Permanent loss is observed at the higher frequencies with a pronounced loss at 4,000 Hz. Permanent loss of hearing can be allayed by keeping the noise dose within specific limits. Very intense sounds can invoke special responses even in a short time. At 120 dB localized discomfort in the ear is experienced, 140 dB produces pain in the ear and the ear drum may be ruptured at levels of 160 dB.

Tests have shown that a person who is at work will become more fatigued than a relaxed person subjected to the same intensity of sound. This probably explains why your neighbours music is too loud when you are studying, and vice versa!

Permanent hearing loss in specific frequency and intensity levels becomes a serious problem for the listener. The problem for pilots is the loss of certain sounds which make the understanding of speech very difficult. Figure 6.56 gives an indication of the sounds, their frequencies, and the intensity levels where they occur. Trying to hear the sound "MMMMM" below about 35 dB would be impossible. "TH" would be lost at less than 10 dB. If a subjects audiogram falls below the values shown, those sounds will not be heard due to hearing loss in that frequency/intesity range. If the sound indicated cannot be heard, speech becomes unintelligible.

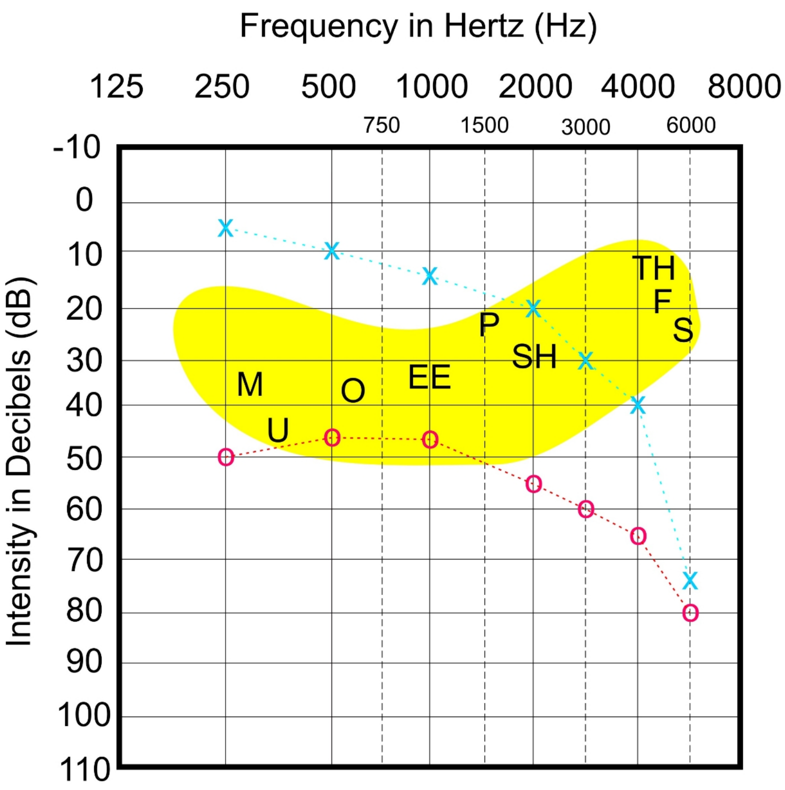


Figure 6.56

Audiogram Speech Range

You will eventually suffer some hearing deterioration as you get older. This is called Presbycusis. The high tones will be the first to go. This will merely add to any level of deafness caused by exposure to noise, and can be a problem as you reach middle age. Looking after your hearing is certainly proof that Prevention is Better than Cure. There is no cure in this case.

Balance

We are very aware of what we see and hear. But unlike vision and hearing, we are usually not aware of the constant barrage of information coming from the specialized organs of balance in the inner ear which react to any movement of the head in relation to what we know is up or down. Take away sight, and things can be very different. Apart from allowing us to hear what is going on around us, the inner ear also fulfils another important function - balance.

The Vestibular Apparatus

The inner ear (Figure 6.57) is made up of the cochlea (the organ of hearing) and the vestibular apparatus (the organ of balance). The vestibular apparatus is made up of the semi-circular canals (which detect angular accelerations of the head) and the otolith organs, the saccule and utricle (which detect linear accelerations).

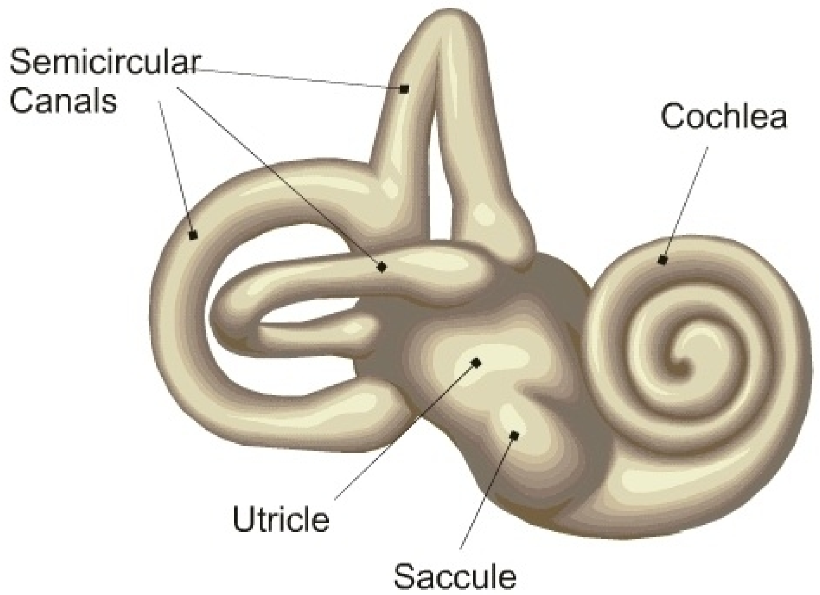


Figure 6.57

The Vestibular Apparatus

The vestibular apparatus is shown in Figure 6.57. It consists of three thin walled tubes - the semicircular canals which are approximately at right angles to each other. They are orientated much in the same way as the three axes of the aircraft - horizontal, lateral and vertical. The semi-circular canals communicate with the otolith organs. Unlike the middle ear which is filled with air, this system is filled with fluid called endolymph and is fixed in relation to the skull. The vestibular apparatus on one side of the head is a mirror image of that on the other side.

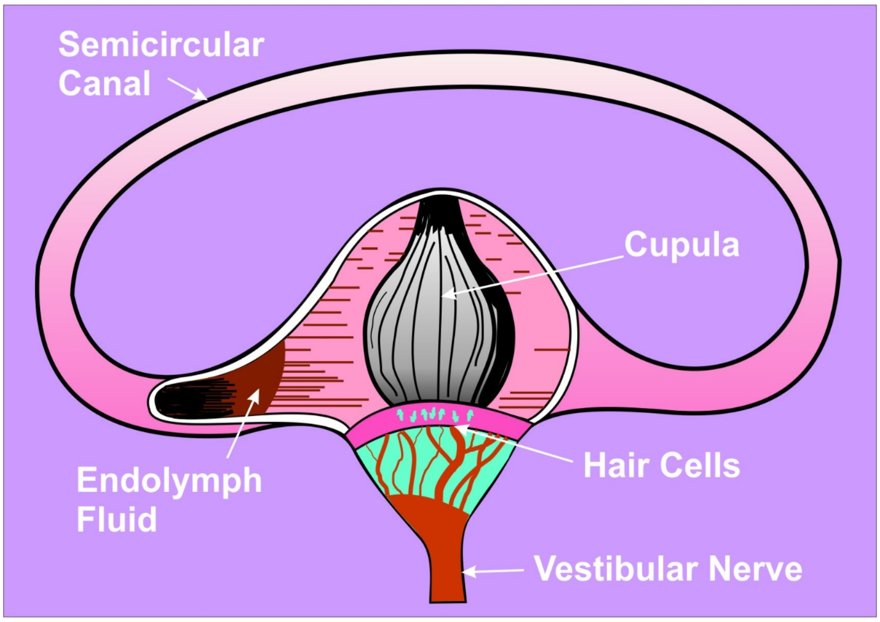


Figure 6.58

Semicircular Canal

Inside the system are very fine hairs which detect movement in any of the three planes. Attach a piece of string to the top of a glass filled with water. Let the string hang in the water. If the glass is turned clockwise, the water's inertia prevents it from moving at the same rate as the glass, and the piece of string will appear to move in a direction opposite to the movement of the glass. After a while, rotating the glass at the same speed, the water will eventually catch up and will rotate at the same speed as the glass. Because the speed of the water and the glass are the same, the piece of string will now be hanging vertically.

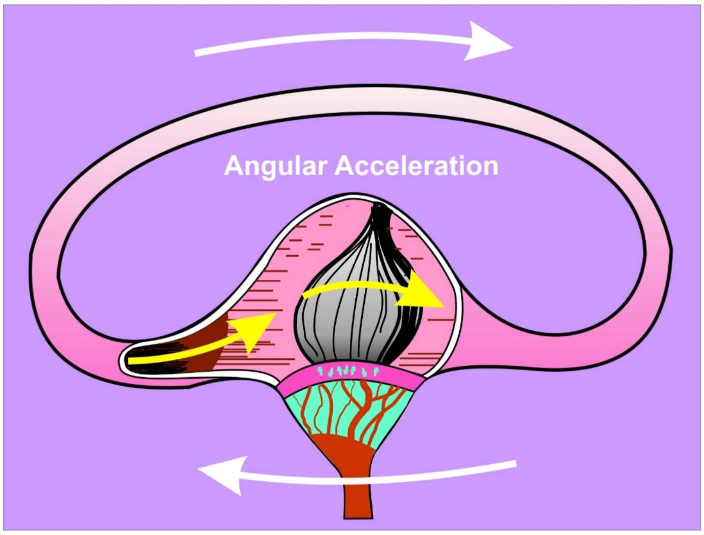


Figure 6.59

Semicircular Canal Rotating

Exactly the same thing happens in the semi-circular canals. Any movement of the head will cause the fluid to lag behind (Figure 6.59), and the fine hairs will react in the same way as the piece of string in the glass of water. After a while, if the movement has been maintained for some time (about 15 - 20 seconds) the fluid in the canals will be moving at the same rate as the head itself, and the hairs will have straightened see Figure 6.60).

It is the movement of the hairs that is transmitted to the brain, which senses the movement. This movement is usually confirmed by our eyesight, as the information is used by the brain to control the eye movements which give us a true picture of what is going on.

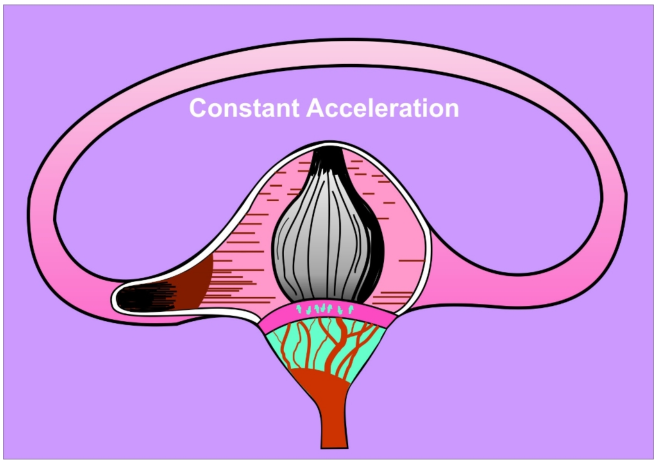


Figure 6.60

Semicircular Canal Constant Acceleration

In an aircraft things can become worse. Consider the glass once again. Slow the rate of rotation of the glass down momentarily. The speed of the water will remain unchanged for a short while due to inertia, and because there is a difference between the speed of the glass and that of the water, the piece of string will move in the direction of the rotation. This is in the opposite direction to the latest acceleration of the glass.

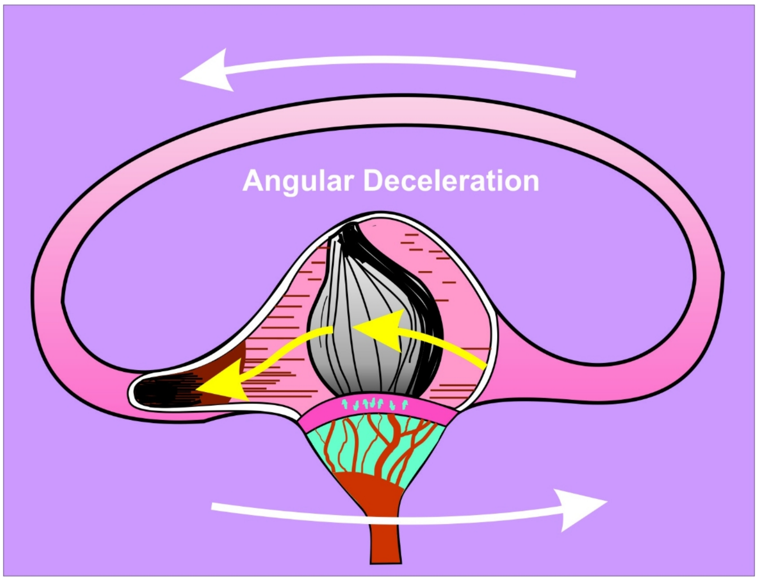


Figure 6.61

Angular Deceleration of the Semicircular Canals

Back to the inner ear again. If a similar situation occurs, the hairs would have originally lagged behind, passing a message to the brain that a clockwise motion was detected. But as soon as the deceleration takes place, the fluid will continue at the same speed, but the canals will slow down. The hairs, like the piece of string will lean away from the direction of the acceleration. The brain interprets this as a rotation in the original direction, opposite to the latest acceleration. But good old eyesight corrects the misinterpretation.

The otoliths can also lead to disorientation. In the same way that the hairs in the vestibular apparatus are affected by rotation, the hairs of the otoliths are affected by linear, or straight line, acceleration. The name otolith means “ear stones” and that is exactly what they are, small particles of calcium carbonate. The inertia of these minute particles causes them to move the hair cells they rest on whenever the head moves. This information is interpreted by the brain as motion. Figure 6.62 shows the orientation of the otoliths when the head is upright.

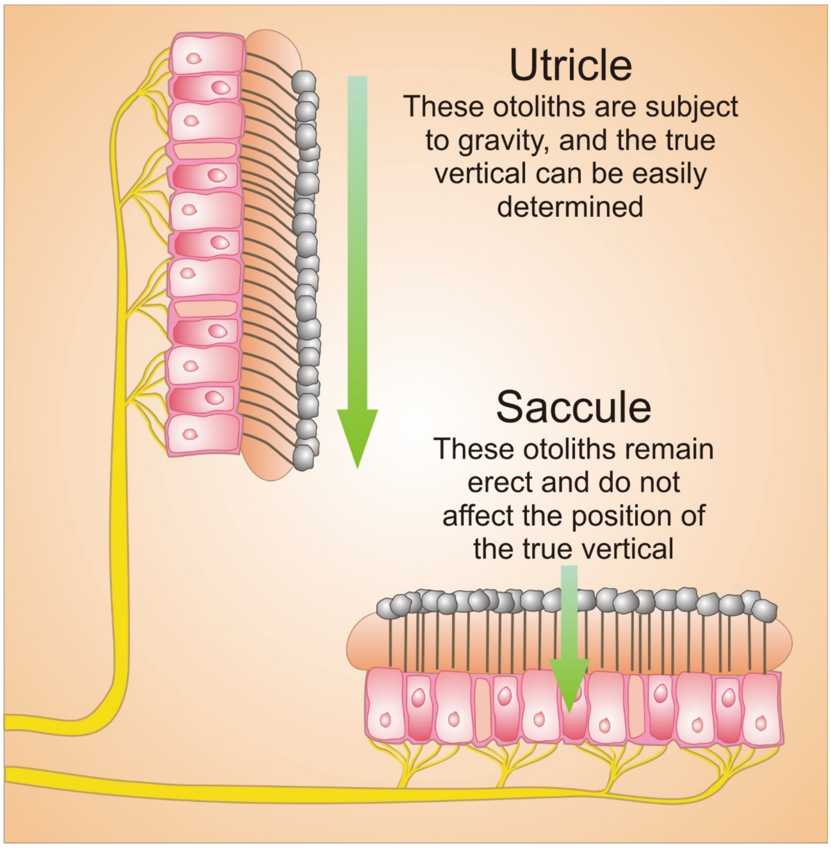


Figure 6.62

The Otolith Organs

When upright, the saccule is sensitive to change in the horizontal, and the saccule provides information about vertical acceleration (you know when an elevator starts moving up or down, thanks to the saccules). If the head is tilted in any way, they change their orientation.

If linear acceleration is experienced, such as during a take-off, the particles will move in the direction of that acceleration. The result is that the true vertical can be misjudged, with possible disastrous consequences see Figure 6.63).

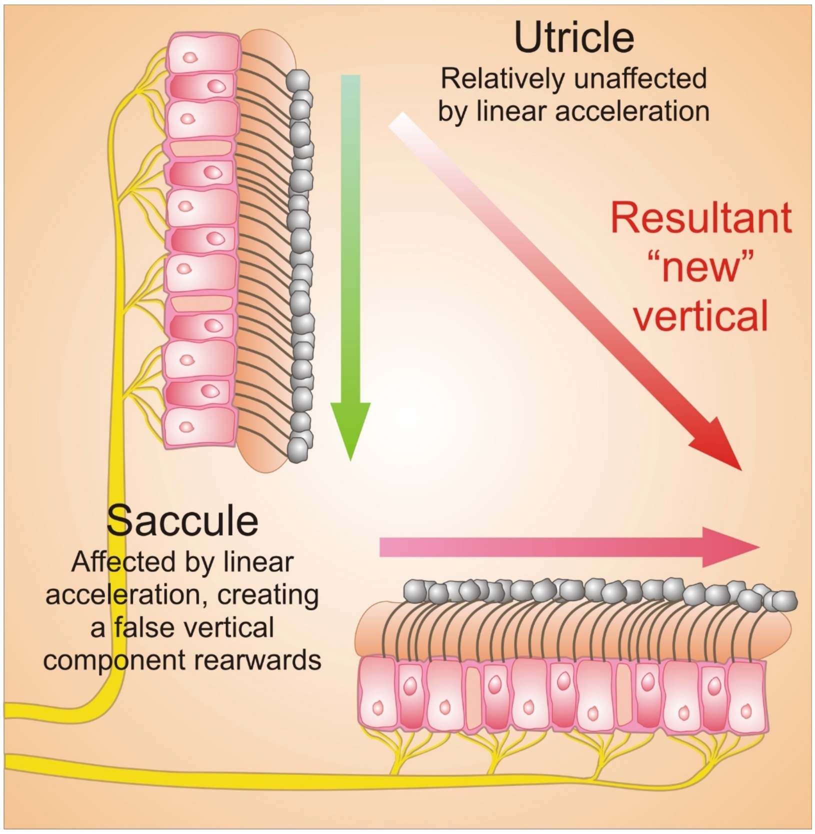


Figure 6.63

Linear Acceleration

The reason for this sensation of pitch-up is the effect that the acceleration has on the otoliths. The rearward movement of the particles on the saccule give rise to a false vertical in the mind of the pilot. This will cause the pilot to push the stick forward.

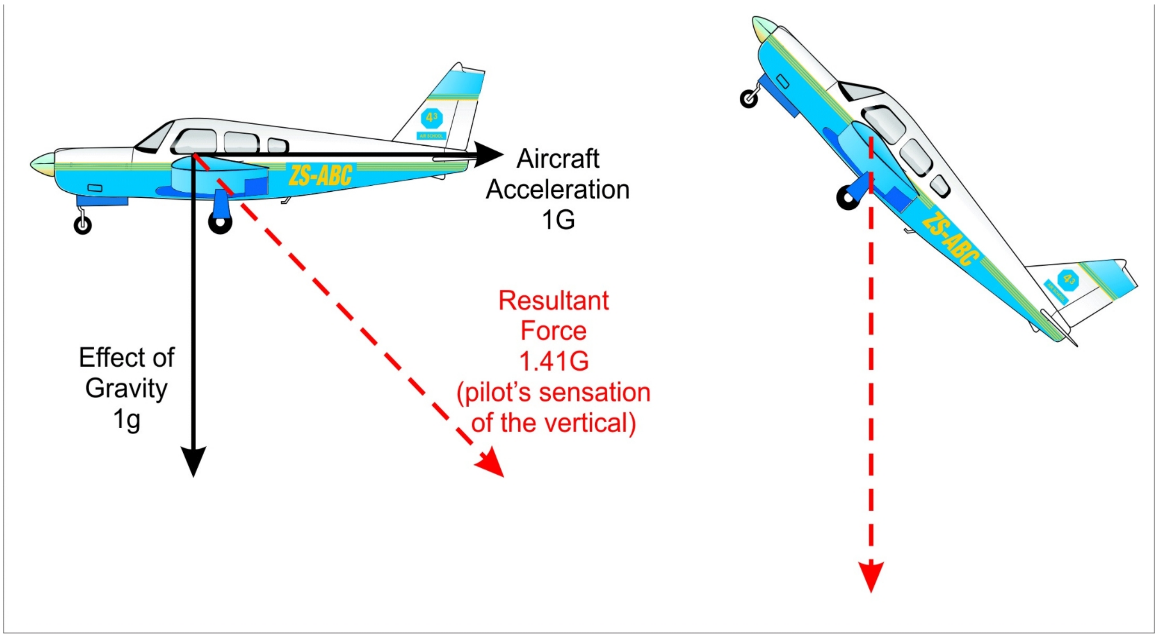


Figure 6.64

The otoliths under linear acceleration

During deceleration, the opposite happens, and the pilot will experience a nose-down sensation resulting in an urge to pull back on the controls. You can clearly see that to push forward on the stick in poor light conditions shortly after take-off could result in an unwelcome contact with the earth. Similarly, to pull back on the stick after taking off power could lead to you stalling the aircraft.

The message to be learnt from this is that our body cannot be relied upon to provide accurate information if visibility is limited. Without our eyes, the brain can be very easily fooled by changing accelerations. A great number of accidents have occurred as a result of this. Private pilots who fly into cloud have ended up losing control of the aircraft, in some cases this will be less than 30 seconds.

Without proper training on how to interpret instrument indications with no other visible cues, private pilots tend rely on their senses for orientation rather then their instruments, and without an instructor present, the chances of an accident are very high indeed.

When we lose the visible cues outside the aircraft, and our senses tell us what is going on (usually incorrectly) the situation is termed Spatial Disorientation, and the best way out of it is:

- DO NOT fly into cloud or poor visibility unless you are properly trained to do so.

- If you get caught out unawares, rely on instrument indications.

- BETTER STILL - Get an Instrument Rating.

There are two major problems associated with the vestibular apparatus. As we have seen from the preceding paragraphs, it is not a reliable system unless other information, mainly visual cues. The second is that the motions which we perceive to have taken place can lead to nausea, in this case motion sickness

Motion sickness

Motion sickness occurs in some individuals when they are subjected to motion, real or imagined, of an unfamiliar form. It usually occurs when there is a conflict of information being provided to the brain by the vestibular apparatus and the eyes. It leads to nausea, vomiting, cold sweating and a pale appearance. It can also cause hyperventilation (over-breathing). It is perfectly normal, but can be very incapacitating.

If you suffer from motion sickness, and there are those unfortunate individuals who suffer on every flight, you will eventually adapt to the strange motion which caused it in the first place, and no longer suffer from it. For this reason it is usually associated with flying training.

If you stay out of the air for a lengthy period, the symptoms may recur until you get used to flying again. Bear in mind that your friends and family who go along as passengers might not fly as regularly as you do, so don't subject them to unnecessary manoeuvres.

Motion sickness can be relieved by medications which can alleviate the symptoms, but these have a detrimental effect on performance, so they may not be taken by pilots, only by passengers. A good bit of advice for any passenger flying with you, is to get them to close their eyes. This removes one of the sources of conflict, and the person should feel a little better. This is not recommended for pilots, however, as it always a good idea to have your eyes open when you fly!

Flying and Health

All pilots must maintain a minimum standard of medical fitness in order to retain their licences. These requirements are clearly stated in CARs Part 67 and SA-CATS-MR. As a Private Pilot you are required to maintain the requirements for a Class 2 medical certificate, but if you wish at some stage to become a professional pilot, a Class 1 medical, for which the requirements are more stringent, is required.

Effect of Common Ailments and Cures

Even minor degrees of ill-health can cause deterioration of flying performance, and the decision whether or not he is fit to fly requires careful thought by a pilot. In general, given the difficulty in making this subjective assessment, it is always better to take the line that any illness sufficient to raise doubts about fitness is probably serious enough to justify cancelling a flight.

The Common Cold, especially if associated with fever as it often is in the early stages, is a good example. Most people will recognize the lethargy, difficulty in concentration, and general malaise felt at the beginning of such an illness and these effects can seriously impair performance. Also associated is congestion of the upper air passages and this can lead to difficulty in equalizing pressure in either the sinuses or the middle ear spaces when in conditions of changing barometric pressure. Severe pain can result from the condition called Barotrauma and this can be incapacitating. In addition, even in the absence of serious pain, a blockage to the middle ear can lead to temporary deafness.

Gastroenteritis, usually from food poisoning, is common in travellers. Nausea and vomiting, diarrhoea, abdominal cramp-like pains, and fever are all common symptoms of this condition and a pilot is unfit to fly while affected. Most attacks are of the short-lived non-specific type known generically as "Travellers* diarrhoea" and will settle spontaneously in two or three days at the most. Treatment with a common gut sedative such as Imodium may control the symptoms until spontaneous recovery occurs, but this does not mean that a pilot so afflicted and medicated is fit to work. In Part 67, Imodium is NOT permitted whilst flying.

Gastroenteritis which does not settle, with or without treatment, in 72 hours needs further investigation as the cause may be a more serious infection such as Salmonella.

Any medication with drugs, whether prescribed or self-purchased, is almost certainly a reason for not flying. A condition whose symptoms are bad enough to need medication could affect performance, and no drugs exist that are completely free from side effects. Examples are drowsiness with anti-histamines which are a common ingredient in proprietary cold cures and hay fever remedies, gastric bleeding with aspirin, and blurring of vision with drugs that stop bowel spasms in gastroenteritis. In general a pilot should seek informed aviation medical opinion before deciding to fly while taking any medication.

Two final points should be noted. First, that new drugs are constantly becoming available, and thus the pilot should consult an Aviation Medical Examiner if he wishes to receive the most up to date advice on the prophylaxis and treatment of illnesses associated with travelling. Second, anybody who develops any illness, especially a fever, on return from a trip outside our borders should seek prompt medical advice and inform the doctor of the locations that have been visited.

Recreational Drugs and Flying Safety

It has been known for years how recreational drugs such as alcohol, tobacco, caffeine and marijuana can dramatically affect aircrew. Accident reports are littered with references to the mental and physical effects of these drugs as contributory factors in aircraft accidents and incidents.

Aviation medical experts are increasingly concerned about this issue. You might argue that an occasional drink and smoke, perhaps ten or twenty a day, couldn't have any real effect on your performance. You are wrong; it could. Cigarettes, coffee, tea and alcohol can have a subtle and often serious impact on flight safety. If we include the effects of the illicit recreational drug, marijuana, it can be worse. One researcher found a startling increase in marijuana usage among aircrew. It was almost as acceptable as smoking cigarettes. Regulatory bodies and aviation operating companies have pretty strict guidelines for aircrew regarding alcohol or other substances, and indeed for other personnel in safety-critical areas. Part 91.02.3 (1) (a) states:

> "no person shall act as a flight crew ember of an aircraft while under the influence of any drug having a narcotic effect".

Alcohol

Your attention is drawn to the contents of Part 91, Rules of the Air, 91.02.3 (2), with respect to the regulations governing alcohol and flying:

> Flight crew member responsibilities
>
> 91.02.3 (2) No flight crew member shall -
>
> (a) consume any alcohol less than 8 hours prior to commencing standby for operational duty or commencing operational duty, which operational duty shall be deemed to commence at the specified reporting time, if applicable;
>
> (b) commence an operational duty period while the concentration of alcohol in any specimen of blood taken from any part of his or her body, is more than 0,02 gram per 100 millilitres; or
>
> (c) consume alcohol during flight duty or whilst on standby, or within eight hours after an accident or reportable incident involving the aircraft, unless the accident or incident was not related to his or her duties.

In the United States, about seven per cent of aviation accidents are related to alcohol misuse. Simulator studies around the world have time and again demonstrated that as blood alcohol concentrations increase, serious error rates rise. Failures of vigilance and lapses in crew co-ordination also increase. These problems were found even at the lowest alcohol level studied, 0.025 per cent. A daily ethanol intake of 80gm or more exposes a person to possible disease, including damage of the liver, central nervous system, gastro-intestinal tract and heart. An intake of 100gm per day or more is hazardous (A normal beer contains about 6gm per 100ml; table wines contain 8- 11gm per 100ml; spirits 32 - 40gm per 100ml.

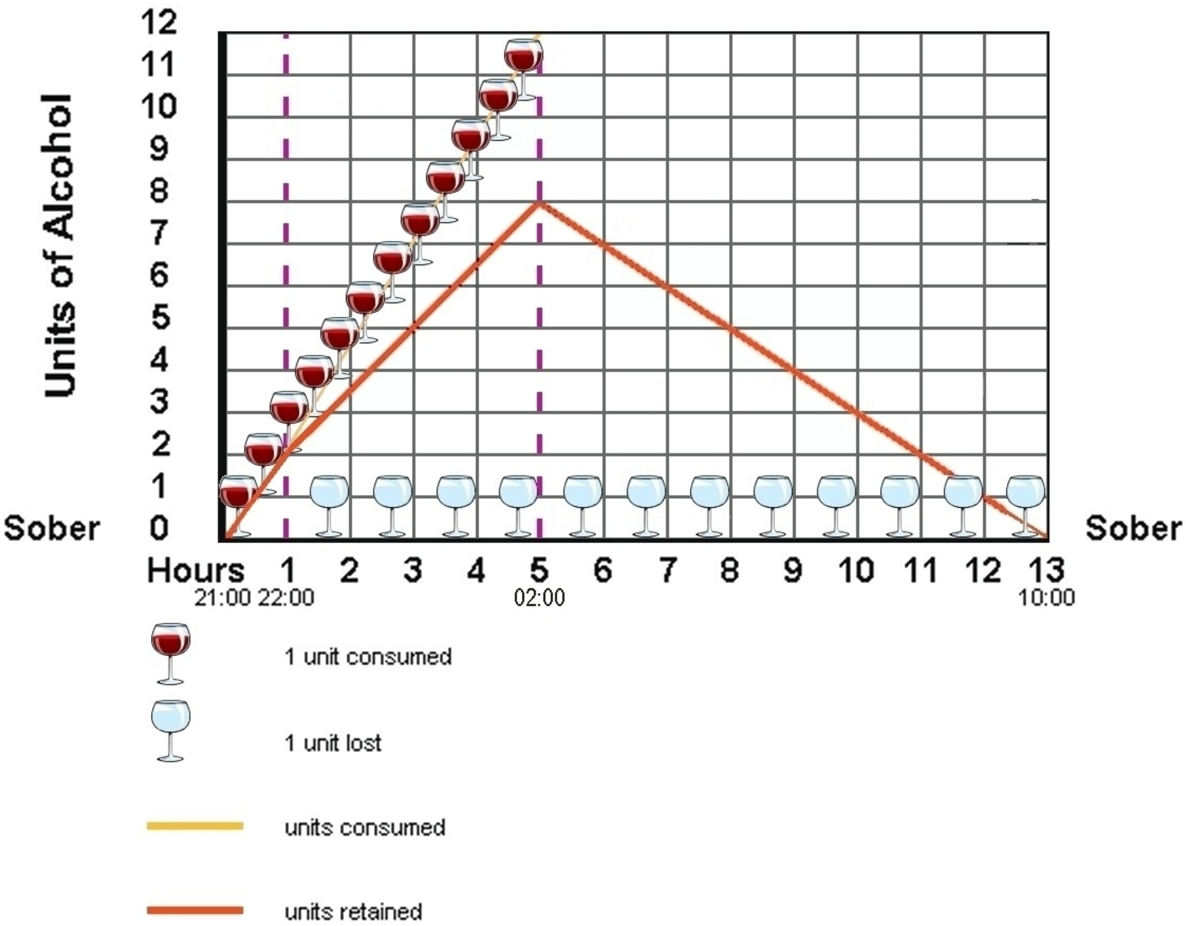


Figure 6.65

Metabolism of Alcohol

Alcohol metabolises at a fairly fixed rate, and as long as there is alcohol present in your blood, you may not fly. This means that after a really heavy drinking session you may still have traces of alcohol in the blood long after the 12 hour period has expired. Contrary to popular belief, there is no way of speeding up the removal rate, and although it varies between individuals and on the time of day, it averages out at about one hour per drink (10 - 15 grams of alcohol per hour). In Figure 6.65 you can see that a person drinking 12 units in a 5 hour period will still have 8 units un-metabolised when the drinking session stops at 01:00. These will take 8 hours to metabolise, so the person will only have removed the alcohol by 08:00. That does mean that the individual is ready for work. The system will still have to recuperate fully before the individual is safe. Simply removing the alcohol does not mean you are ready for an effective day’s work.

Alcohol abuse is a potent contributory factor in aircraft accidents, the same way it is factored into motor vehicle and industrial accidents. In Australia, alcohol-related disease is a significant cause of temporary or permanent loss of aviation qualifications. For up to seventy-two hours after even mild intoxication, there can be measurable degradation of psychomotor performance, decision-making, visual acuity and the ability to track and maintain a target; a zero blood alcohol level, even in the presence of hangover symptoms, does not equate to the return of normal human performance.

Habitual use of alcohol results is:

a. central nervous system tolerance, in which the dependent person can sustain an increasing alcohol intake yet go about his or her business at a blood alcohol concentration that would incapacitate the non-tolerant drinker

b. peripheral nervous system disease which can produce altered sensation and function of the lower limbs due to irreversible nerve damage

c. organ damage resulting from toxic effects on cells, particularly in the liver, central nervous system, gastro-intestinal tract and heart

d. interference with vision, balance, co-ordination and motor functions

e. predisposition to other serious diseases such as diabetes, pancreatitis, epilepsy and vitamin deficiency syndromes

f. serious impairment of psychomotor skills, reaction times, judgement, decision-making and cognitive function

If you have a hangover it can affect any safety-critical procedure. Changes to the density of fluid in your ear canals due to alcohol can affect your balance, and are compounded by hypoxia and turbulence. Your fine motor skills will be impaired, and you will find yourself flying less smoothly and have more susceptibility to disorientation and motion sickness. If you try to offset fatigue with an increase of caffeine and cigarettes, you will further interfere with your metabolic, physiological and cognitive functions.

The effect of alcohol on the body is very similar to hypoxia. This will obviously reduce ones tolerance to altitude and positive accelerations (High G).

The solution is to either not drink, or to drink in moderation.

Caffeine

How many times a day do you have a cup of coffee? Too many, perhaps, because we feel in need of a “pick-me-up”.

After drinking coffee (average caffeine content between 75 and 100 milligrams), the caffeine is almost completely absorbed within fifteen to forty-five minutes, the clinical effects lasting approximately three hours. Research evidence suggests that complex decision-making and problem-solving are unaffected by caffeine consumption. However, some harmful effects are recognised: caffeine is a diuretic (it makes you pee!) and can cause dehydration; and suddenly stopping a regular caffeine intake can be associated with some unpleasant withdrawal effects such as irritability, difficulty in concentrating, headache, tremor and difficulty in sleeping.

Tobacco

There is no question that the dangers of tobacco smoking are well documented and backed up by overwhelming medical evidence - It can cause serious cardiovascular disease, bronchitis, emphysema and lung cancer. Smoking impairs the haemoglobin transport of oxygen in the blood to vital organs, reducing its effectiveness by up to ten per cent. It can also have subtle, usually unnoticed cerebral effects, especially if compounded by altitude-induced hypoxia and cold.

Above 4,000 feet the effects of smoking become apparent, in particular the impairment of night vision and visual acuity Colour perception is also reduced- Although withdrawal effects after stopping smoking vary considerably, it can result in nausea, headaches, increased appetite, irritability and insomnia. Symptoms may persist for weeks and sometimes longer.

Research has shown that three cigarettes smoked at sea level can raise your physiological altitude to 8,000 feet. The reason goes back to the characteristics of haemoglobin. This combines with oxygen in direct proportion to the oxygen partial pressure in the lung cells. Tobacco smoke also exerts a partial pressure along with the other gases inhaled. It is the minute amount of carbon dioxide in tobacco smoke that can seriously affect your physiological altitude, for two reasons - First, haemoglobin combines with carbon monoxide approximately two hundred times as readily as it does with oxygen. Once this is combined, the resistance to separation is in the same proportion. Secondly, regardless of oxygen partial pressure, combination of haemoglobin with carbon monoxide reduces the amount of haemoglobin available to carry oxygen and carbon dioxide. Thus, the longer the carbon monoxide is available in the lungs, even in minute amounts, the less oxygen is carried in the blood.

Marijuana

The immediate effects of smoking marijuana include the creation of a pleasant dreamlike state, with impairment of attention, cognitive and psychomotor performance. This appears reversible to the person smoking it. Because of it$_5$ perceived lack of acute, life-threatening effects, cannabis has been termed a soft or recreational drug. It has been described as no more damaging than coffee or tobacco. Medically this is not true, as the drug*s impairing effects are on memory and learning, as well as on the lungs, immune defences, brain and reproductive function.

Many polyaromatic hydrocarbons have been identified in marijuana smoke some of which are known to be carcinogenic. There is also strong evidence to suggest that (like tobacco smoking) it can cause cancer of the mouth, larynx, tongue, upper jaw and respiratory tract. Cannabis and its by-products are highly fat soluble and are stored in the body’s fat, liver, lung and spleen for lengthy periods. Its longer-term effects, although not known in any detail, are certainly adverse to human health.

The aftermath (day after) effects of marijuana can lead to mood swings, lack of alertness and impairment of the operation of complicated equipment. Some reports suggest that marijuana may be up to 4,000 times more potent (that is gram for gram) than alcohol, in producing decrements in the performance of subjects studied under controlled conditions. Heavy usage runs the risk of experiencing psychotic symptoms. Over a long period, there could be subtle forms of cognitive impairment which persist while the user remains chronically intoxicated. The additional downside of this is that it may not reverse after abstinence.

There is definitely no place for any form of cannabis use in the aviation environment. Even the infrequent, so-called recreational user of cannabis could easily put others at risk the day after smoking it.

Summary

a. Alcohol. For up to seventy-two hours after even mild intoxication, there is a measurable degradation of psychomotor performance, decision-making, visual acuity, and the ability to track and maintain a target. The effects arc aggravated by altitude-induced hypoxia and reduced temperature.

b. Caffeine. Can cause dehydration. Withdrawal effects can lead to difficulty in concentrating.

c. Tobacco. Impairs oxygen-carrying ability of the blood. At 8,000 - 10,000 feet visual acuity and colour perception are reduced.

d. Marijuana. Impaired attention, cognitive and psychomotor performance for at least twenty-four hours, possibly longer.

Scuba Diving - precautions before flying

This is another aspect which is regulated by law. Part 91 (91.02.3) states that: "No person shall act as a flight crew member of an aircraft within 24 hours following scuba diving by such crew member". The reason for this restriction is because of the possibility of contracting decompression sickness, or the "bends".

Decompression sickness is very rare among recreational pilots, as one of the prerequisites is that the cabin altitude must be above 18 000 feet, or better still, above 26 000 feet. Not very likely in a small single-engine aircraft.

We have to contend with Henry's Law here. What happens is that the nitrogen in the blood stream comes out of the solution in the form of bubbles if there is a rapid ascent, due to the decrease in pressure, resulting in the nitrogen expanding. This usually takes place via normal respiration, but if it happens too quickly, decompression sickness is possible.

This is normally in the form of pain in the joints known as the "bends", the "chokes" - a choking sensation with pain in the chest, formication or the "creeps"- a tingling sensation feeling like ants crawling over the skin, and the "staggers" which affects the brain and can lead to muscular dis-coordination.

What must be considered from a flying point of view is the depth to which the scuba diving took place. At 100 feet below the surface the pressure is 4 atmospheres (every 33 feet is an additional one), and nitrogen is forced into solution at a high rate. If the subject were then to surface, get into an aircraft and start climbing, the amount of nitrogen in solution in the blood might be sufficient to be forced out as pressure decreases. Then decompression sickness can be contracted at much lower flight altitudes.

The treatment for decompression sickness is to land as soon as possible and seek medical attention.

Toxic hazards

There are numerous substances in aviation which are toxic. Fumes from fuel, hydraulic fluid, anti-icing fluid, and fire extinguishers, among others, can all affect the way we perform. The vapour from fuel and lubricants may be an irritant and can lead to drowsiness if inhaled. A dry powder fire extinguisher, if said off, could cause suffocation or lung irritation. Worst case scenarios lead to dizziness, confusion and coma.

A further problem arises in the event of a fire. Seemingly harmless components have the potential to become toxic. The insulation on electrical wiring is a very good example. Set it alight, and the gas it produces is very toxic, as well as burning the eyes, making it very difficult to see.

Carbon Monoxide. This is the most important of all the toxic hazards in aviation. It usually enters the cockpit via the heating system, and is dangerous because it is odourless and colourless. And it can kill you. It is not limited to the heating system, but is produced in all fires. This could even be the aircraft upholstery or your baggage.

The symptoms of carbon monoxide poisoning are headache, breathlessness, impaired judgement (not always discernible) and finally, loss of consciousness, which in itself makes it rather difficult to fly an aircraft. One of the few indications you may be able to pick up is what is referred to as a "cherry-red" complexion.

If you smell anything that appears to be fuel, it will not be carbon monoxide (remember that it is odourless) but is unburnt fuel that has come from the exhaust. This will always be accompanied by carbon monoxide, and is a good indication of its presence. Open all air vents and switch off the heater.

Dangerous Goods. There is a whole section of Aviation Law (Part 92) dedicated to the carriage of dangerous goods. To sum it up as simply as possible, don't carry anything that can burn (unless it is fuel in the fuel tank!).

Passenger Care

Many of the problems discussed in the preceding paragraphs relate only to flight crew. After all, it doesn't really matter if a passenger becomes spatially disorientated, does it?. But passengers can, and do suffer from hypoxia, hyperventilation, carbon monoxide poisoning, decompression sickness and motion sickness. And they fly with head colds. You must always bear in mind that you are responsible for their safety and their comfort.

BASIC PSYCHOLOGY

Human Information Processing

The whole process which we call flying involves see and do. We observe events which take place in the cockpit or the environment in which we are flying, and then we react to them. In doing so we rely on our senses to help us make the decisions, and then take the actions which will ensure a safe outcome.

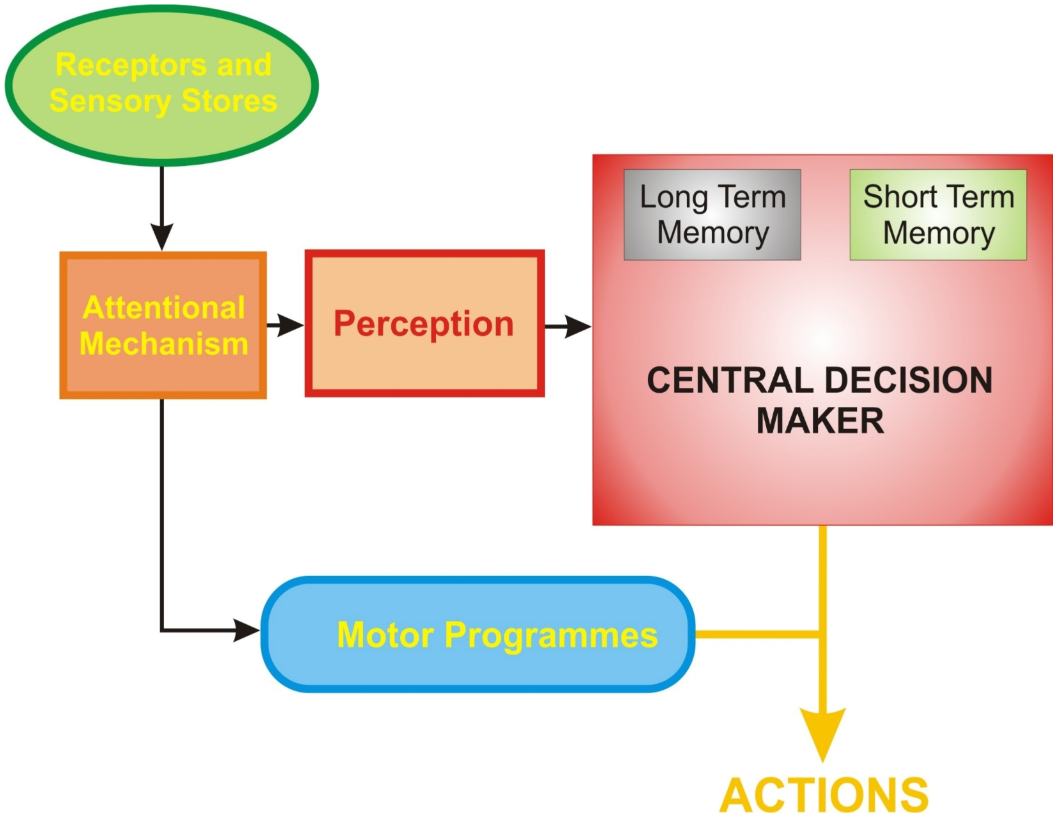


Figure 6.66

Human Information Processing

Without getting too technical about the whole process, we must understand that the brain reacts to various stimuli, perceives the situation, and then arrives at a solution using whatever is stored in our memory bank. The result is then performed as a response to the original stimuli.

Our senses which are all connected to the brain via the spinal chord. This is known as the central nervous system. One or more of our senses is activated (sight, sound, smell, taste, feel) and the brain is activated. This initial activation of the senses produces sensation. Sensation deals with the events involved in the external and internal stimuli encountered by the receptor cells of a sensory organ. Sensation is the first stage in the events that begin with the effect of a stimulus upon the receptor cells of a sensory organ, which then leads to perception. This is what we interpret the sensation as being. Sensations are the first stages in the functioning of senses.

Perception is our interpretation of what we have sensed, and this is an important part of what we do next. If we perceive the sensation to be what it isn't, we will react to what we think we see, hear, etc. When someone mentions the word garlic, or orange, we are able to smell both mentally without actually having seen the two items. We can picture the orange in our mind's eye, and we know exactly what it feels like. This is stored knowledge which is known as cognitive knowledge.

An example of this is being pricked by a pin, or putting a hand onto something very hot. Without much thought going into the process, we react by moving away or withdrawing our hand. Even if the hot plate of the stave is turned off, we will react as if it was actually switched on as this is our perception of the situation. This is an automatic reaction, or motor programme. Most of us can walk and chew gum at the same time, without having to actually think about either action. We change gear in a motor car without having to look at the gear lever while doing so.

How we make decisions can be illustrated quite simply by Figure 6.66. The initial step is the sensation in the receptors and sensory stores (see, hear, etc.) which leads on to our interpretation of the event (perception). The central decision maker is then brought into play, and we analyse the situation, drawing on past experiences or knowledge of the event stored in memory. This is the actual decision making stage, or thinking. We then make a choice and perform the action we feel to be best for the situation.

If we have performed a certain task numerous times, we may develop motor programmes which we can perform without much conscious thought. This allows us to bypass the central decision making process and jump from stimulus or perception straight to action.

In flying, however, very little is of an automatic nature. There has to be a conscious process to solve problems which are usually fairly complex, and then we find ourselves limited in the number of things we can do at the same time. We have to train ourselves to tackle each problem separately by first prioritizing the required tasks, then spending a little longer on each one, rather than switching quickly from one to another. And while doing so, we have still to monitor other aspects of the flight.

You will find yourself with long periods of time when nothing seems to be going on, and then suddenly find that your workload increases out of all proportion. For obvious reasons the required workload in the cockpit is going to be highest during take-off and landing. Add the odd aircraft emergency, a strange request from ATC, and a low fuel state, and things can go cock-eyed.

As you gain experience, you will find that the amount of conscious thought that goes into a decision will reduce, and with time, our response may become automatic as is the case with the gear change in the motor car.

As you gain more experience, you will find that at first you had to consciously think about each action that is required for a particular task. Later, with practice, you will find that a set of separate components of any action will become integrated. Finally, these actions can be carried out with very little conscious thought. Downwind vital actions are a typical example of this. With time they become easier and easier to do. All we have to do is take the initial decision to carry out the action, and the rest comes easily.

As things become easier and easier to do, we must be careful of falling into a state of complacency. Anticipation of an event could lead us to minimising our options is we are expecting a good result. We must still monitor what is being done, otherwise things will become a habit. And habits have a habit of becoming bad! This is a very good reason why multi-crew operations make use of the "challenge and response" method of the check list.

Because we start to do things automatically, it is important to remember that the way we respond to any stimuli is affected by several factors:

a. If we have to make a decision under pressure, especially if a delay in making the decision could be catastrophic, then it is possible that we may make the decision without considering all the information available.

b. If we are in a state of high arousal, for example, on finals, with the aircraft on fire, the nose wheel not locked down, a thunderstorm overhead, and ATC asking what our intentions are, our performance will deteriorate. We may well react fast enough, but the response could be the wrong one.

c. A very loud alarm going off will more likely attract your attention than any visual stimuli, so you would most likely respond in error to the alarm than the visual stimulus.

d. If you are expecting something to happen, you will respond very quickly if the expected stimulus actually occurs. But if something unexpected occurs while you are waiting in anticipation, then it very likely that you will carry out the expected response in error, without considering the new stimuli.

e. As you get older, you will become slower in your responses, but the good news is that they will become more accurate!

Divided and Sustained Attention

Many tasks require divided attention, that is, sharing attention among several aspects of the environment. Driving is a divided attention task, as is piloting an aircraft. Other tasks require sustained, concentrated attention to detect small changes in displays or control panels. An example is air traffic control.

Divided Attention - Defined as the ability to perform more than one task at a time. The ability to perform these tasks successfully depends in part on the nature of the tasks and whether or not they use the same or different cognitive processes. If the tasks draw upon different processes there is a higher likelihood that the tasks can be successfully performed concurrently. If the tasks require use of the same cognitive processes, it is less likely the tasks will be performed within acceptable time and accuracy parameters. The more similar the tasks, the more difficult it will be to perform them simultaneous. Also, the more difficult the tasks, the harder it will be to perform then simultaneously, although this may be somewhat ameliorated by practice.

Sustained Attention - Sustained attention requires concentrating on one primary task for a long period of time while remaining alert to changes. With the increased use of automated systems, many jobs have changed from "active doing" to monitoring or "supervising" systems. Unfortunately, humans are notoriously poor at these types of tasks. It has been consistently found that human performance quickly deteriorates over time as we become less vigilant.

Verbal Communication

Based on the channels used for communicating, the process of communication can be broadly classified as verbal communication and non-verbal communication. Verbal communication includes written and oral communication whereas the non-verbal communication includes body language, facial expressions and visuals diagrams or pictures used for communication.

Oral Communication

The oral communication refers to the spoken words in the communication process. Surprisingly, only about 7% of all communication is oral, ie., the message itself. Oral communication can either be face-to-face communication or a conversation over the phone or on the voice chat over the Internet. Spoken conversations or dialogues are influenced by voice modulation, pitch, volume and even the speed and clarity of speaking.

Nonverbal Communication

Nonverbal Communication-information that is communicated without using words. It includes specific visual, sense and sound. Vocal sounds that are not considered to be words, such as a low sound, or singing a wordless note, are nonverbal. It is mostly used to express emotion in different context. Body language is very important in communication, and makes up about 55% of the communication. Many of our body movements can override the spoken message. Constantly looking at your watch while listening to somebody makes them uneasy as your are basically telling them to hurry up without actually saying so. Folding your arms across your chest is a way of trying to shut someone out of your private space. This will obviously not play a part in radio or telephone conversations. Yet how often do you see people talking on their cell phones while giving elaborate directions with their arms?

Paralanguage

Paralanguage is the study of nonverbal cues of the voice. Various acoustic properties of speech such as tone, pitch and accent, can all give off nonverbal cues. Paralanguage may change the meaning of words. It is basically how you say what you are saying, and contributes about 38% of all communication. Imagine trying to pass on very bad news to someone while laughing your head off!!

Proxemics

The nonverbal study of space and distance. The concept of territorial space refers to the area around the self that a person will not allow another person to enter without consent.

Distance Zones

We don't like our "space" to be invaded, unless we are very fond of the person involved. Be careful when trying to communicate effectively that you The zones can be divided as follows:

a. Intimate : (up to 2 feet), most sensitive zone, since it is reserved for close friends, and loved ones.

b. Personal : (2 to 4 feet)

c. Social : (4 to 12 feet)

d. Public : (greater than 12 feet)

Memory

The human memory which plays such an important role in our decision-making can be divided into three separate types. These are the sensory store, working, or short term memory, and long term memory (see Figure 6.67).

The sensory store is constantly being presented new information through all of our sense, but we will concentrate on iconic (vision) and echoic (hearing). All that we see and hear enters the sensory memory. Unless we actually use the information, it will soon be lost, as it is replaced by new information. Visual information is lost quickest and only lasts in our sensory store for about a quarter of a second - what where you looking at about 15 seconds ago - and is then lost. Our echoic memory lasts a little longer, upwards of three to four seconds. An example of echoic memory is to get someone to recite a list of random numbers, and then suddenly stop, asking you to repeat the last four numbers. You will be able to "replay" the numbers in your echoic store. If there was no pause between the time your friend stopped reciting the numbers and asking you to repeat them, you will be able to pick up the last few numbers and recite them quite accurately. If there was pause between the time your friend stopped counting to the time you were asked to repeat them, your recall will be poorer because the information would have left your echoic memory. About 1% of information entering our sensory store moves on to working memory.

A good demonstration of the duration of the sensory store is to ask someone who has just looked at their watch for the time. Invariably they will have to look again to see what the time is!

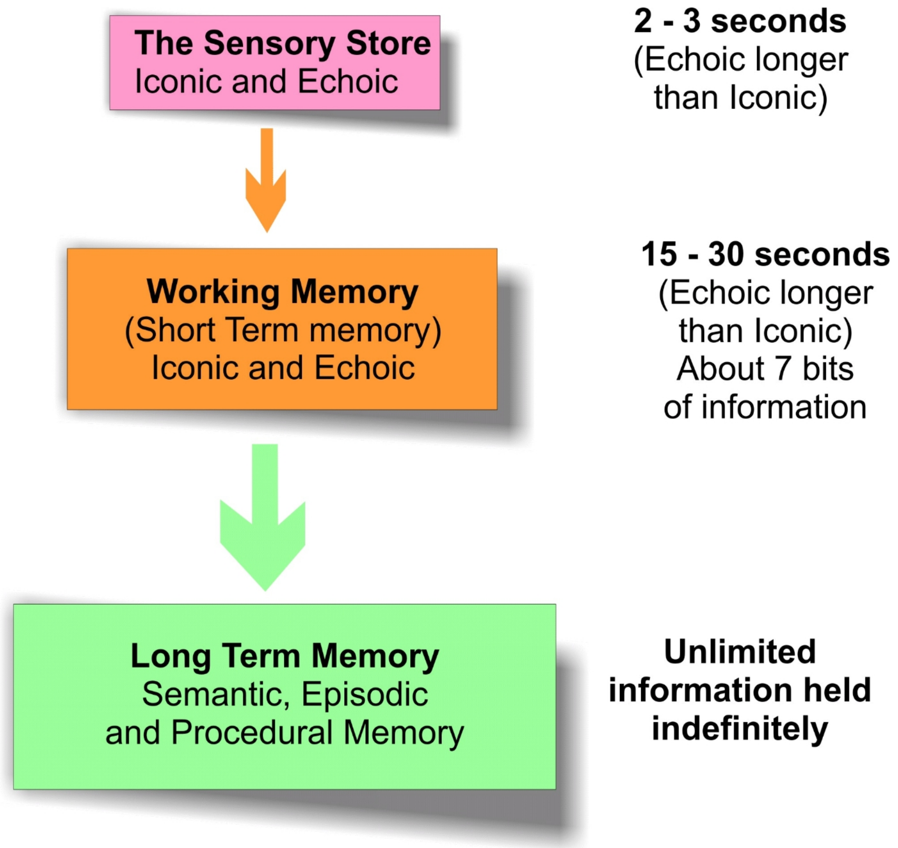


Figure 6. 67

The Structure of Human Memory

Working, or short term memory, is also broken into iconic and echoic, and lasts a little longer than the sensory store. Here we are looking at about 15 to 30 seconds. Once agin echoic will last for longer than iconic.

It is believed that an average of about 7 items can be stored in the short term memory. Some suggest 7+2, but the average is a lot fewer as it depends on the information being given. You are likely to remember more words that you are familiar with than words that you seldom use.

We can expand our ability to remember things by a process called "chunking". Here information is organised into meaningful groups. An example is the following series of unrelated numbers:

1 1 2 1 4 4 2 7 1 2 2 5

It would be very difficult to remember the 12 digits if they were shown to you for a very short period, even if you were asked to remember the sequence. However, instead of being presented with 12 digits, let us consider that you were given 4 dates instead: New Year's Day (January 1), Valentines Day (February 14), Freedom Day (April 27), and Christmas Day (December 25). The digits are the same, and in the same sequence, but you would only have 4 items to remember, and you would have freed up memory space to store additional information.

1 1 / 2 1 4 / 4 2 7 / 1 2 2 5

Most of us do this without being aware of it when remembering telephone numbers, we tend to chunk the information into three groups: first the service provider code (083), then a three-digit chunk (302) and lastly a four-digit chunk (1848). This method is far more effective than attempting to remember a string of 10 unrelated digits.

Long term memory has three subdivisions:

a. Semantic memory, which refers to the words and facts that we have stored. This is our knowledge bank.

b. Episodic memory, which refers to our memories of specific events at specific times. It is almost a stored autobiography.

c. Procedural memory, also called motor programmes, or muscle memory, refers to the use of objects and the movements of our body. You can't explain how to ride a bicycle but you can show how.

The amount of information that can be stored in long term memory is regarded as unlimited, and the duration is indefinite. It is possible for information to be lost, such as in cases of amnesia (memory loss) and certain illnesses such as Alzheimer’s Disease. In both cases this is usually only from the episodic memory. People who suffer from episodic memory loss are still able to walk and talk so motor skills and semantic memory appear to be largely unaffected.

They can’t remember where they are, who they are, and what has happened in the recent past. This can also happen after a very traumatic event (such as a flying accident) when the brain shuts out the memory of it.

Stress

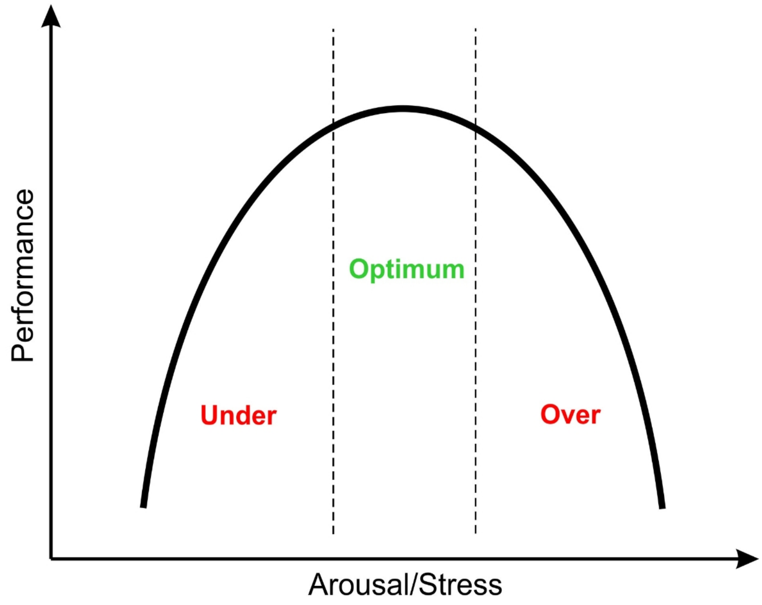


Figure 6.68

Arousal Levels

We all need stress. We need it simply to get our bodies to react to the demands which are placed upon it. And anything that causes stress is called a stressor. The problems start when the amount of stress placed on is becomes too much for us. From Figure 6.68 it can be seen that performance is poor when we are subjected to too little, or too much stress or arousal. To operate effectively, we need to be in the optimum zone. If we spend too much time in the over arousal zone, we will become stressed.

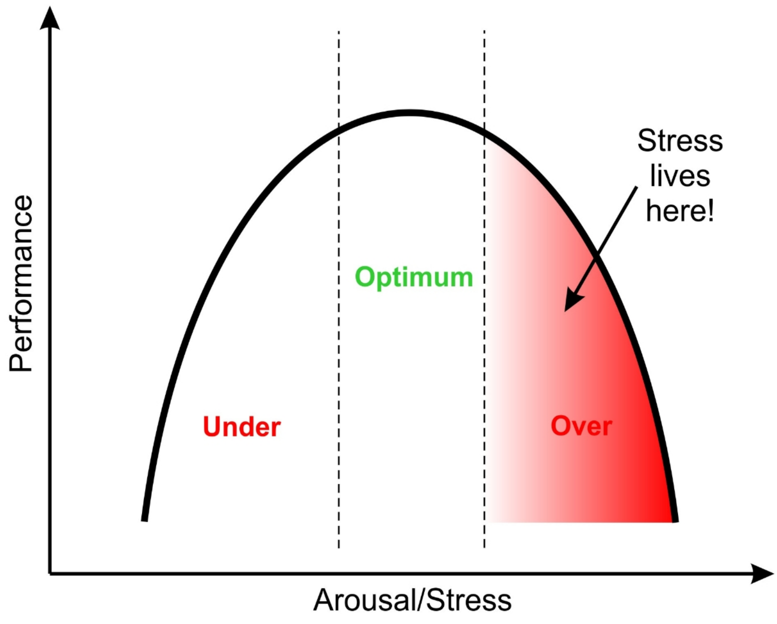


Figure 6.69

Constant Over Arousal Leads to Stress

The fact that we suffer from stress is by and large our own doing. It is said that stress doesn't exist, only stressful situations. Stress is very different in people. One person may react completely differently to exactly the same situation as another. It is therefore our perception of the situation that determines our response. If I believe it to be impossible, I won't try, or if I believe that I do not have the ability, I will most likely give up, or not try at all.

Stressors can be divided into three main categories: Physical, Physiological and Emotional stressors.

Physical stressors are very common in aviation. We operate aircrafts in an environment where we have conditions of temperature extremes, high and low humidity, noise, vibration and hypoxia. Most of these can be overcome by design and systems in the aircraft.

Physiological stressors are problem associated with the human element and include fatigue, sleep loss, hypoglycaemia (low blood sugar) caused by missed meals, and illness.

Emotional stressors include all the things that go on in our social and emotional lives. These include domestic problems, emotional problems, financial problems, bereavement and time commitments.

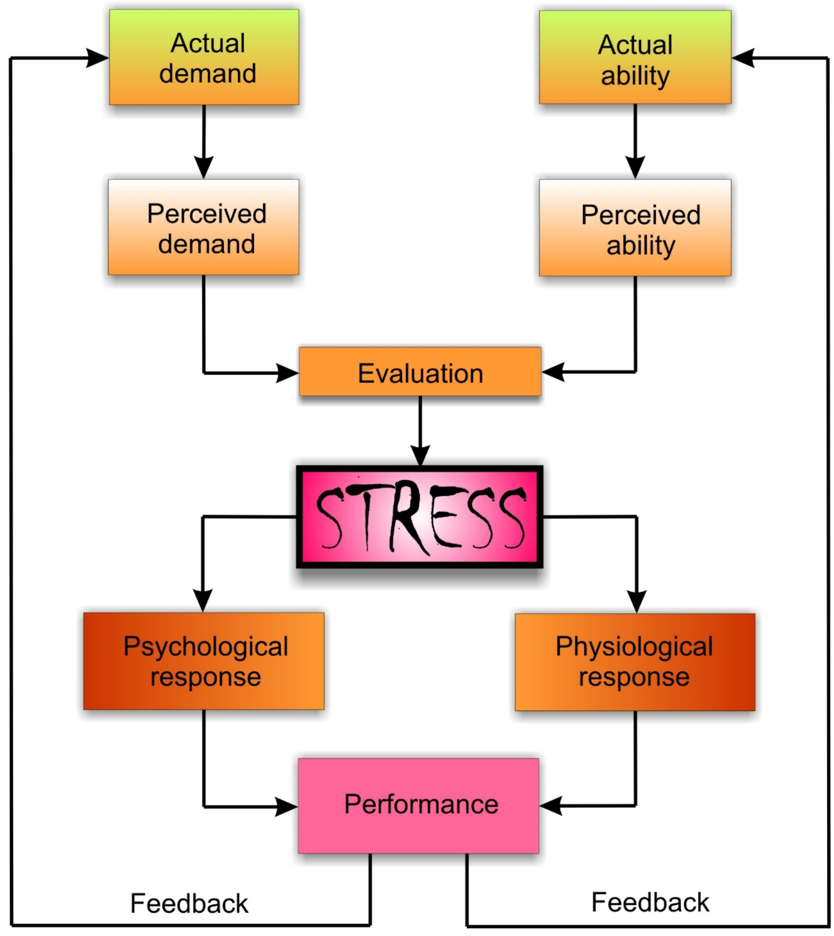


Figure 6.70

Processes Which Cause Stress

The problem we have with too much stress is that our own performance is affected more than we would like to believe. There are two categories of stress, namely Acute and Chronic.

Acute stress is fairly common in aviation with the high demands placed on us. The situations are usually short lived, and most of us tend to cope fairly well. But stress has a far greater effect on the performance of more difficult tasks. Excessive stress may cause you to concentrate on only one aspect of a problem at the expense of all other factors. We can therefore find ourselves in a situation where there can be too little, or too much, stress. And somewhere in between there is the optimum level of stress, or arousal, which will bring out the best in all of us.

Too little stress, or too much, and we underperform. So we need to have just the right amount of stress to perform optimally. If we are confronted with a difficult task, the level of stress should be in the favour of lower stress, and for an easy task, we need a bit more of a kick to keep us interested.

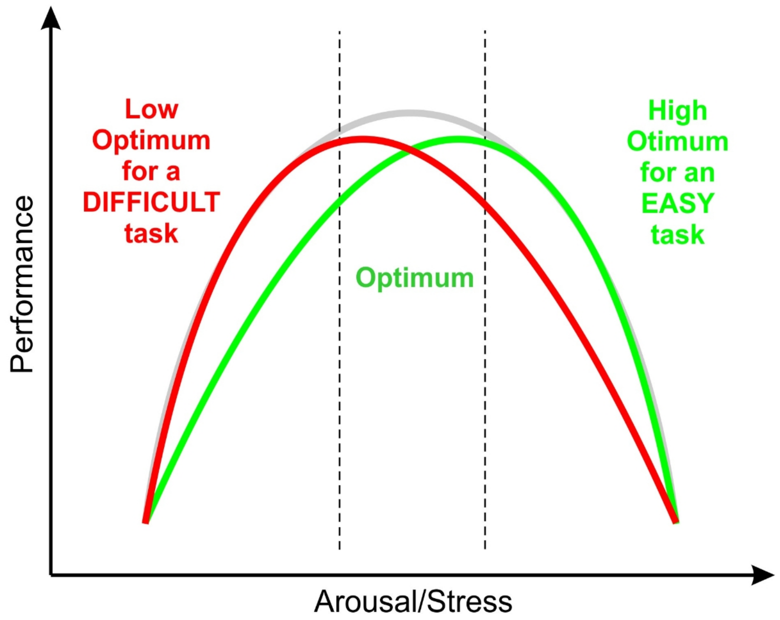


Figure 6.71

Relationship Between Stress (Arousal) and Performance

The problem arises when we have a situation where we have a situation of chronic stress. This is an accumulation of long-term demands which have been placed on us. And the stressors don't necessarily have be negative by nature. If you perform well on a course or test, you are under pressure to repeat or improve your performance. Any emotional problems we take into the cockpit with us are unwanted baggage, and will definitely affect our performance.

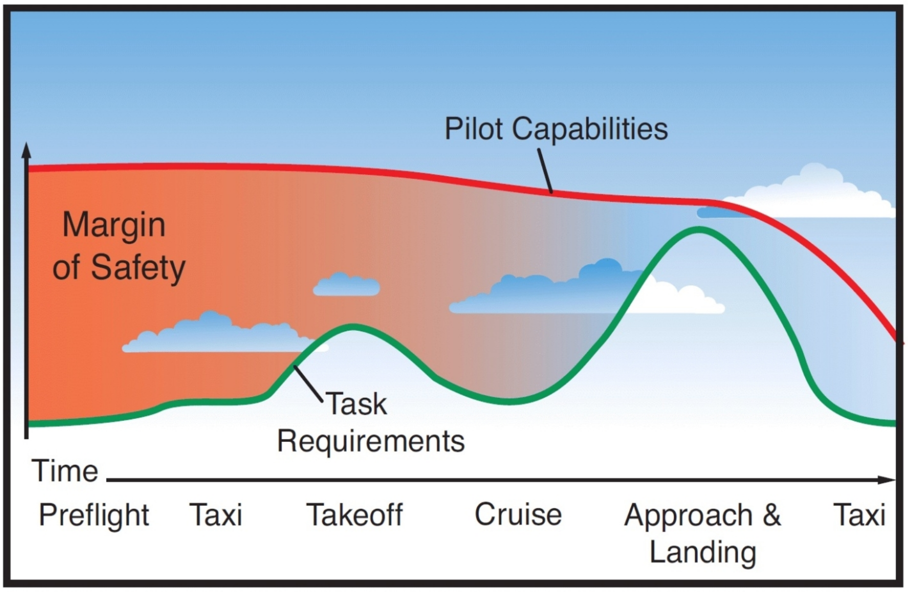


Figure 6.72

Pilot Capabilities Available vs Task Requirements

Chronic stress can exaggerate the effects of acute stress, and a task we are normally able to perform with a great deal of ease will become more difficult. And complex tasks could become impossible. As a flight progresses, we become more fatigued. Your capabilities are reduced as a result, and any sudden demand could leave you short of the desired input. Figure 6.72 shows the Pilot Capabilities Available vs Task Requirements. If the Task requirements become greater than what the pilot has to offer, there is no longer a margin of safety and an accident is a distinct possibility. Figure 6.72 also shows why so many accidents occur during an approach. The margin of safety is minimal during the approach and landing, and any emergency or distraction could place too high a demand on the pilot, and an accident is a possibility. If you started the flight tired, there may be no margin of safety available.

As a pilot you need to be aware of the effects of stress. A very good sign that someone is under severe stress is that they tend to withdraw more and more into themselves. Verbal communication reduces, and this could be very critical, especially in a multi-crew situation.

The dangers of not addressing stress is that it can become too much for us. A good indication is the high percentage of people with high blood pressure. our bodies battle to keep up with the demands being placed on them, and if we don't do anything about it, we could lose control totally as a result of sheer tranquilliser.

Identify the stressors, and do something about them. Identify them all, and treat them one at a time, starting with the more serious ones. Don't try and hide away from reality. Speak to a family member, a friend, a counsellor, or a minister of religion. Regular exercise helps reduce tension. Learn to relax. It is sometimes very difficult to admit that we are experiencing problems (after all, pilots are "macho" aren't they?), because we fear that others will see it as a weakness or a lack of competence.

Coping Strategies

There are three basic approaches to coping with stress. These are:

a. Action Coping. When we find ourselves in a stressful situation that isn't going to go away, there are two options available to us, the cause of the stress must be removed, or we must move away from the stressor. Divorce is a good example of action coping. Absenteeism is another.

b. Cognitive Coping. We use this when we cannot change the situation and we have to stay. In this case, the only way open is to rationalise and reduce the impact of the stress on ourselves. Stress is all to do with perception, so if we can reduce the perceived magnitude of the stress, we have managed to reduce its impact on us.

c. Symptom-directed coping. Here we try to remove the symptoms of the stress. Some will turn to drugs (tranquillisers), alcohol, tobacco, or caffeine. Clearly this will only offer temporary relief, and the problem wont go away. Other types of symptom-directed coping health and fitness programmes, learning relaxation techniques (meditation, self-hypnosis, yoga), and religious practices. For many people some form of regular religious practice helps then cope with stress, an example being a bereavement in the family.

Be aware that stress can and will influence your performance in the cockpit, especially in an emergency situation. Do something about it, and never take your unwanted baggage on board an aircraft.

Fatigue

As is the case with stress, there are two types of fatigue that affect a pilot. The first, called Acute fatigue, is caused by intense mental or physical activity at a single task. Examples of this are having to work extremely hard on an important problem while under pressure, or flying in instrument conditions in turbulence for four or five hours. Anytime you have to give a task your undivided attention for a prolonged period, you are likely to suffer from acute fatigue.

The second type of fatigue is Chronic fatigue. It is caused over time by such factors as lack of sleep, jet lag, and stress. Acute fatigue can be cured by rest, such as a good night*s sleep. However, chronic fatigue may take much longer to disappear, and can only be alleviated if the root causes are eliminated.

Fatigue affects every part your performance. It degrades attention and concentration resulting in missed cues or information; it affects decision making; it has a negative impact on coordination; and it makes you less able to deal with other people, particularly in situations of conflict,

Fatigue also tends to focus your attention on things that require activity rather than thought and lowers your ability to handle the multiple tasks associated with flying. Furthermore, it lowers your discipline, encouraging you to accept greater margins of error or risk than you would if alert. When fatigued, it is difficult to muster the enthusiasm and energy to pay attention to detail.

Recommendations in this regard are simple. Avoid flying when fatigued. Always try to have a full night's sleep before you fly, and do not fly after an exhausting day at work. Give yourself time to relax before a flight and time to prepare for it mentally.

If you become fatigued during a flight, land and rest. This is often a difficult decision to make, because sometimes the growing fatigue forces you to concentrate so hard on the flying that you are not consciously aware of how tired you are. Furthermore, once a journey has started, it is much more difficult to interrupt it for something as seemingly intangible as tiredness.

Fatigue is frequently linked with pilot error and you should never underestimate its detrimental effects. For this very reason, in Part 91 of CARs, under Rules of the Air : Flight crew member responsibilities, Rule 91.02.3 (1) (d) states:

> No person shall act as a flight crew member of an aircraft if a flight crew member knows or suspects that he or she is suffering from, or having due regard to the circumstances of the flight to be undertaken, is likely to suffer from fatigue to such an extent that it may endanger the safety of the aircraft or its occupants.

Sleep

It doesn't seem fair. Right when you are exhausted after a stressful event, you come down with a cold. That is no accident or a stroke of bad luck. Sleep is essential to the immune system. Without adequate sleep, the immune system becomes weak, and the body becomes more vulnerable to infection and disease.

Sleep is also the time of rest and repair of neurons. Neurons are the freeways of the nervous system that carry out both voluntary commands, like reading these notes, and involuntary commands, like breathing.

To get the best out of sleep you need to develop good sleep hygiene. Infants need far more sleep than adults, about 16 hours per day. As children grow older they need less sleep, with teenagers requiring about 9 hours per night. Adults need about 7- 8 hours of sleep per day. Notice that there is no differentiation between a "young" adult and an old one. Teenagers and "young" adults have trouble getting enough sleep not only because of their "busy" schedules, but they are biologically programmed to want to stay up later and sleep later in the morning. Unfortunately this does not go very well with flying schedules!

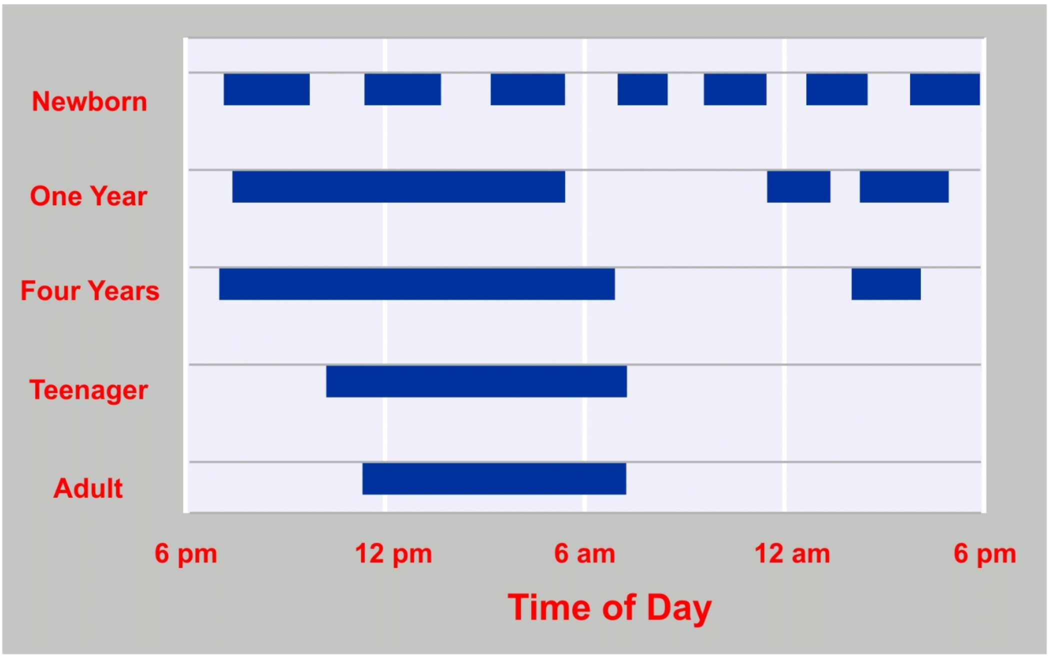


Figure 6.73

Sleep Requirements

The aviation industry is a non-stop, 24-hours per day, 365 days a year activity. As a PPL you will rarely be called upon to fly at unusual times, but the holder of a professional flying licence will most certainly be. The professional pilot is therefore very aware of sleep requirements. This does not mean that as a PPL you do not sleep - we all do. Sleep is essential.

Sleep is closely linked to what is known as our biological rhythm, also known as our circadian rhythm (circa - about, dies - the day). This is the pattern of temperature variations which our body experiences or the period of a day. It is easier to fall asleep when the body temperature is low - think of an animal in hibernation during winter - and more difficult to do so when the body temperature is rising.

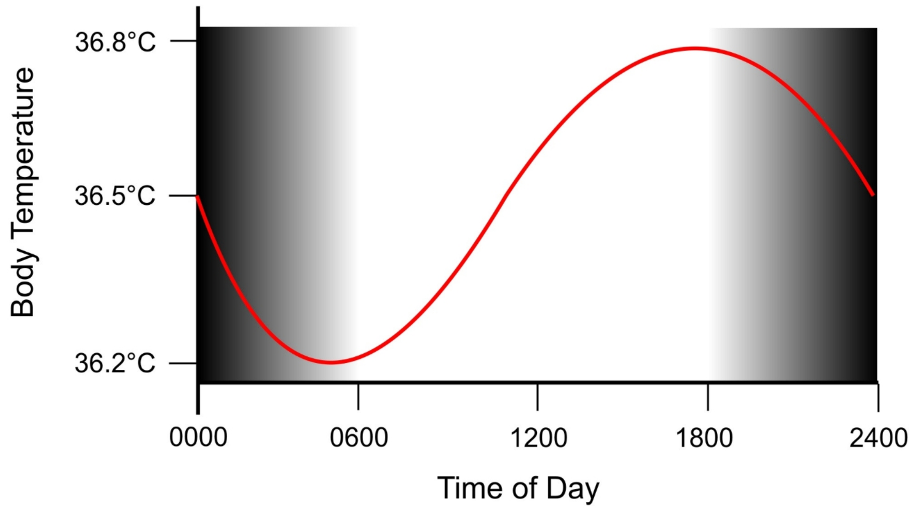


Figure 6.74

Circadian Rhythm

Sleep has distinctive stages that cycle throughout the night. There are four stages of sleep known very simply as Stage 1, Stage 2, etc. Then there is a fifth stage known as REM, or Rapid Eye Movement.

These five stages occur in sequence over a period of about 90 minutes, and then the whole is repeated (see Figure 6.75). It is believed that the first four stages, also known as slow wave or deep sleep (the deepest being Stage 4) allow for body restoration. The fifth stage, or REM, allows for brain restoration. It is almost as if you are de-fragging your own computer, and storing everything on your hard drive.

As your sleep cycle starts you will spend more time in deep sleep (Stage 4) and then progressively less the night wears on. During the course of the night you will spend most time in Stage 2.

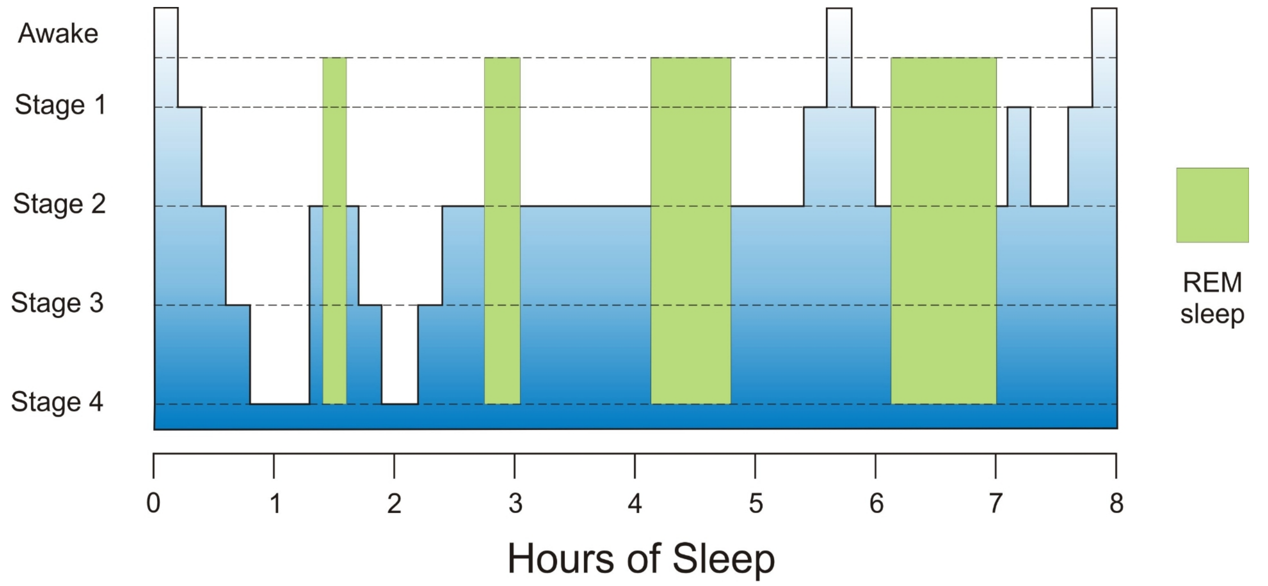


Figure 6.75

Sleep Cycles

REM sleep will increase in each subsequent cycle. The longest period of REM occurs during the final phase of sleep just prior to waking. If you start your sleep late into the night, you will be depriving yourself of REM, but will get good body restoration

The normal sleep requirement is 8 hours per night. This leaves 16 hours available for all of our other activities - work, recreation, etc. One hour of sleep gives two hours credit (see Figure 6.76).

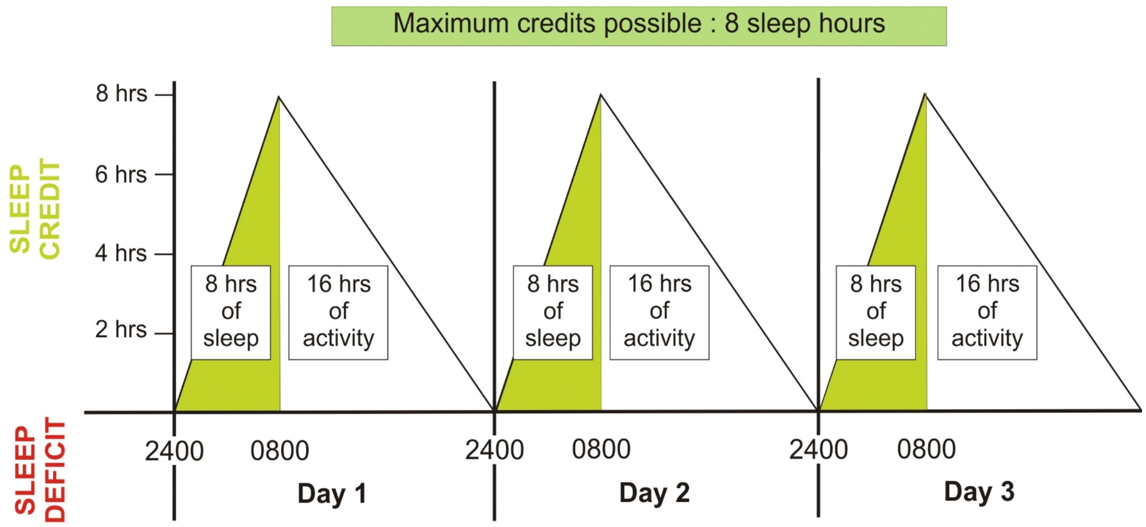


Figure 6.76

Normal Sleep/Awake Cycle

Figure 6.77 shows the correlation between the ideal sleep pattern and the human biological clock. When the body temperature is dropping, a person is more likely to sleep. Body temperature increase is related to improved physical activity.

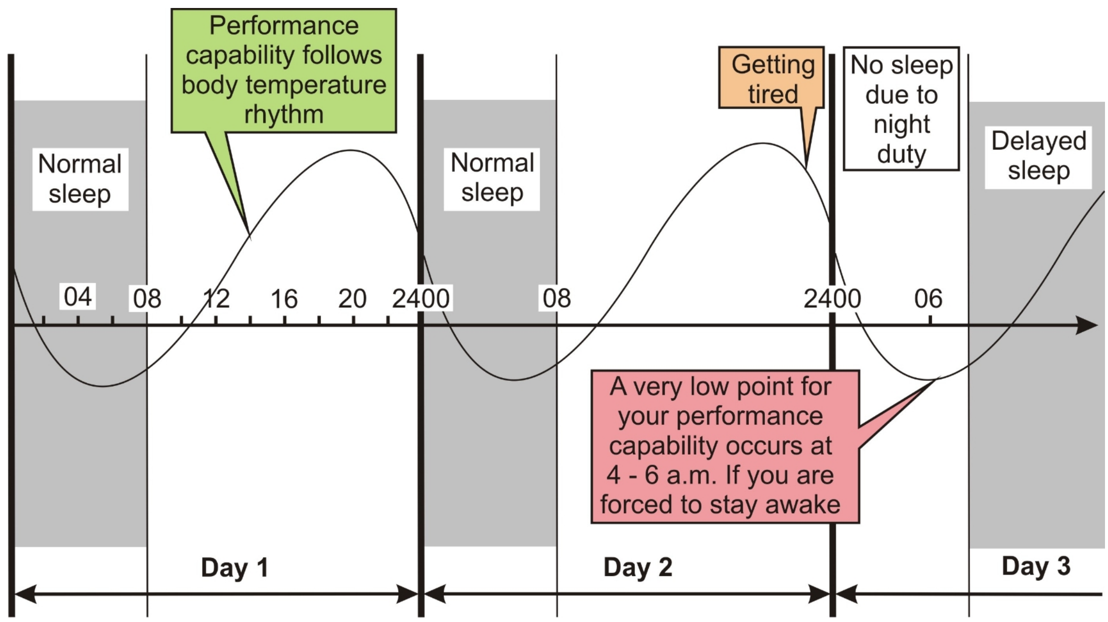


Figure 6.77

Sleep vs Biological Rhythm

When sleep is delayed due to late work or just a late night out with friends, you get into sleep deficit. It is not necessary to sleep the full amount of deficit to catch up on lost sleep, as it has been shown that about one third of the lost sleep will be sufficient to get you back to normal. If the deficit becomes too large, performance will deteriorate to the extent that the subject becomes a danger, no t only to him/herself, but to others as well. A cockpit is no place for anyone suffering from sleep deficit. CARs Part 91

> Flight crew member responsibilities 91.02.3 (1) No person shall act as a flight crew member of an aircraft (d) if the flight crew member knows or suspects that he or she is suffering from or, having due regard to the circumstances of the flight to be undertaken, is likely to suffer from fatigue to such an extent that it may endanger the safety of the aircraft or its occupants.

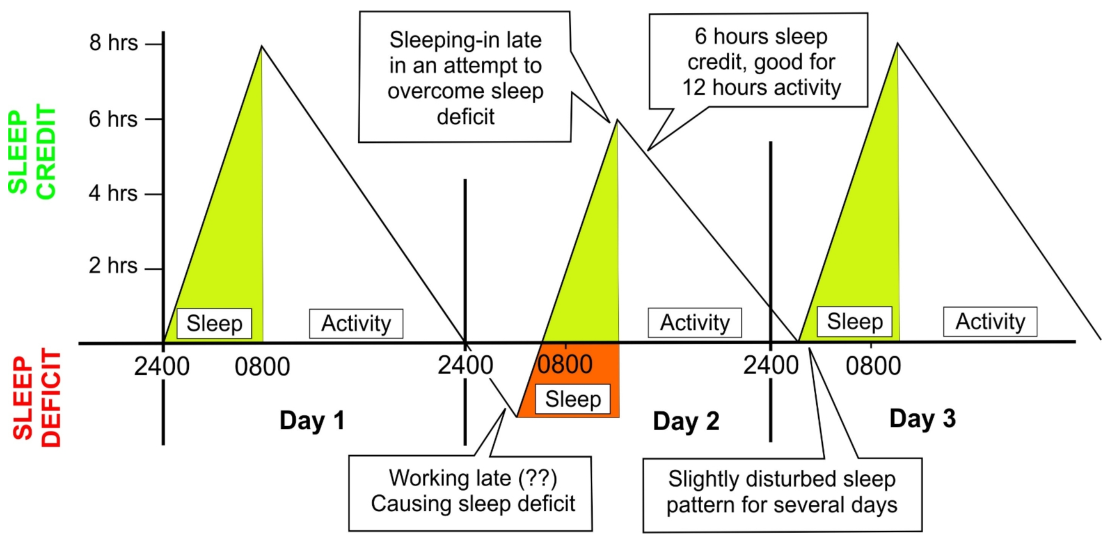


Figure 6.78

The Effect of Disrupted Sleep Hygiene

It is important to manage your sleep hygiene properly. It is the timing of sleep rather than the time spent awake that is the important factor influencing sleep. Sleep is easier, and longer, when the body temperature is falling.

Crossing Time Zones (Jet Lag)

Unlike the 24-hour “clock” day, the human body will have a natural rhythm of about 25 hours. It is cues like the sun that allow us to adapt to the 24 hours with little difficulty. These cues are known as “zeitgebers”. The word is German, meaning “time givers”. When you cross time zones, it the 25 hour body clock that creates the problem by being disrupted. This is known as circadian disrhythmia, or “Jet Lag”.

When travelling in a westerly direction (with the sun), the day effectively becomes longer. In an easterly direction the day becomes shorter. Those of you who have flown in an easterly direction towards the Far East will be aware of the fact that night comes along very quickly, and that soon after an early afternoon take-off, the cabin crew starts preparing for dinner! On westbound flights, most take-offs are at night, so you are not really aware of the change.

Using an example of a flight between London and New York, we cab see the cause and effect of jet lag. There is a 5 hour time difference between the two cities. At local midday in London (1200Z), the time in New York is only 0700 local. If you fly to New York, the day will end at 2400 local time, while it is already 0500 local time in London the next day. You have effectively made the day 29 hours long. Your own body clock, tuned to a 25-hour day, will be out by 4 hours - giving you an effective 4 hours of jet lag (29 - 25 = 4).

On the return trip, local midday in New York is at 1700Z. Arriving back in London, midnight will come five hours earlier than in New York, making the day 19 hours long. Your body clock, set at 25 hours, will now give you an effective 6 hours of jet lag (25 - 19 = 6).

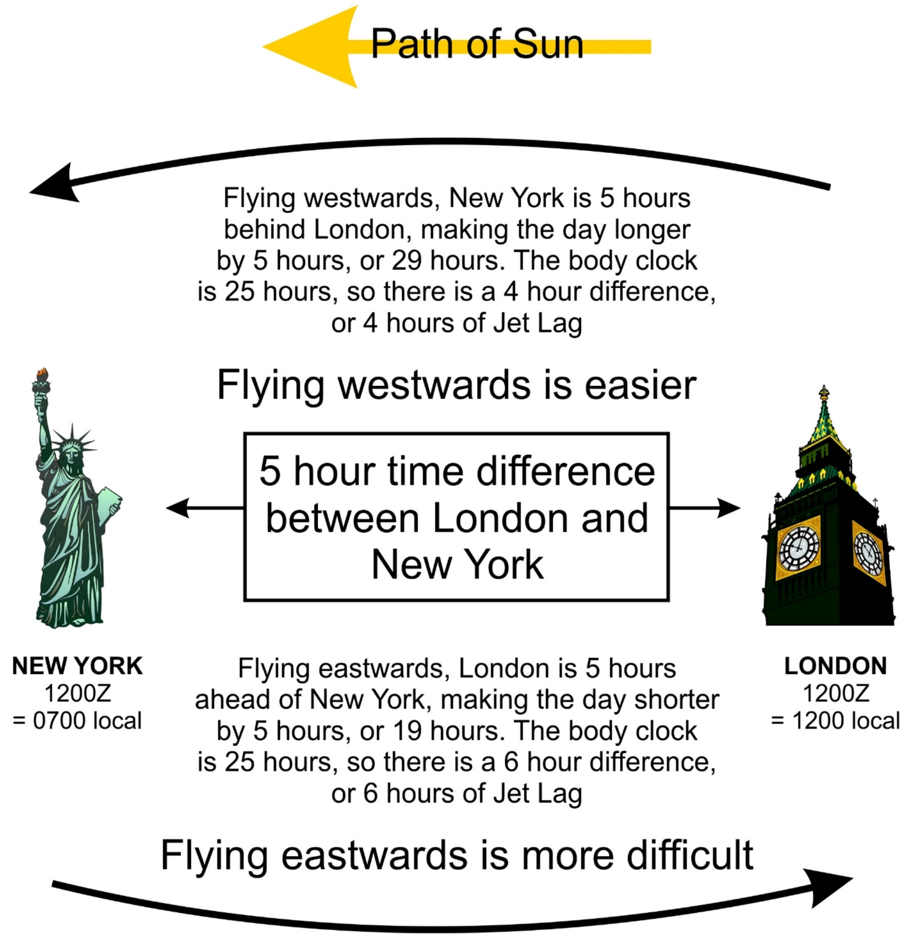


Figure 6.79

Effect of Crossing Time Zones (Jet Lag)

The body is able to readjust to the new time zone at a rate of about 1 to 1,5 hours per day. This will result in the person travelling westbound being fully recovered in about 3 to 4 days. The person travelling eastbound will take about 4 to 6 days to readjust the 6 hours of jet lag, making it more difficult to cope with eastbound flights.

To get the benefit of the faster recovery rate (1,5 hours per day), you need to make use of zeitgebers, the best of which is the sun. Being out of doors during local midday at your destination will speed the process up a bit.

Travelling north/south does not cause jet lag.

Sleep Disorders

The inability to fall asleep is called insomnia. If you are unable to fall asleep due to noise or jet lag, it is known as situational insomnia. However, if conditions are perfect for sleep, and you are unable to do so, you are suffering from clinical insomnia, and may need medical intervention.

Other sleep disorders are:

a. sleep walking (somnambulism) and sleep talking (somniloquism);

b. apnoea, which is a temporary cessation of breathing. This starts off with events lasting about 10 seconds a few times a night. They tend to increase in frequency and duration as the subject grows older and could become a problem, especially those who are heavy snorers; and

c. narcolepsy, a condition where sufferers are unable to prevent themselves from falling asleep, even if in sleep credit. This is clearly a dangerous situation for flying, and is a disqualifying condition.

Judgement and Decision Making

Good judgement is an essential tool in the life of a pilot. Luckily it can be learned. Judgement and decision making go hand in hand, and poor judgement can often lead to poor decisions being made. Many accidents have occurred due to poor judgement, rather than poor operating skills. Good judgement involves several steps, and should never be a "spur of the moment" operation. Many things have to be considered before making any decision, and good judgement is what leads to better decisions being made. Judgement is the mental process used to make a decision.

Some factors affecting judgement are:

a. Knowledge - do you have sufficient data to use, are you current with regards the facts?

b. Commitment - am I going to use the SOPs or do it my way?

c. Skills - do I have the necessary skills to make the decision and carry out the required action?

d. Recognising errors - do I monitor my actions and reconsider other options.

There are two extremes when we consider judgement. At one end of the spectrum we have perceptual judgement. This involves the motor programmes which are the learned responses that we have learned over time. Flying training is designed to develop these automatic responses by developing motor programmes. How many times does a student pilot repeat the approach and landing before being let loose on his/her own? The development of this judgement will free up our brain to cope with other actions requiring a more considered response.

The second form is known as cognitive judgement and is the result of using memory. Decisions have to be considered based upon knowledge. This can be termed thinking. This applies to unrehearsed or new situations which have to be carefully considered before any decision may be made.

In the cockpit you will be called upon to make many decisions. Decision making is solving problems by selecting a course of action from several possible alternatives. The behaviour of any skilled individual such as a pilot can be broken down to three basic categories:

a. Skill-based behaviour. These are the stored routines which we have learned with practice and developed over time, and allow us to perform routine tasks without much conscious thought. They are the motor programmes stored in our long term memory. We use these routines in familiar situations. We can also refer to these actions as automatic, being triggered by simple "signals". People using skill-based behaviour may be unable to describe how they work, as these routines have become automatic.

b. Rule-based behaviour. This requires more conscious effort than skill-based behaviour. This involves a set of stored rules, written down such as a checklist, or stored in the memory. This behaviour is found in familiar but non-routine situations. The individual will recognise certain cues and then follows a set of learned rules and procedures.

c. Knowledge-based behaviour. This is used in unfamiliar situations with no or few rules available to them from past experience. Based on individual perception, a goal is set, and a plan put into action using knowledge stored in memory.

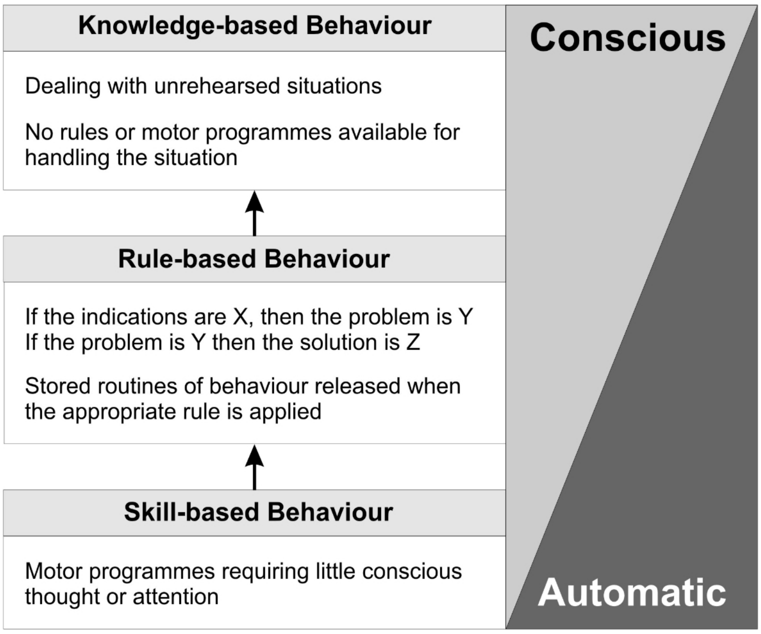


Figure 6.80

Relationship Between Behaviours

Errors

If decisions are based on these three forms of behaviour, it stands to reason the errors may be made at each level. These errors which occur are classified in the same three categories.

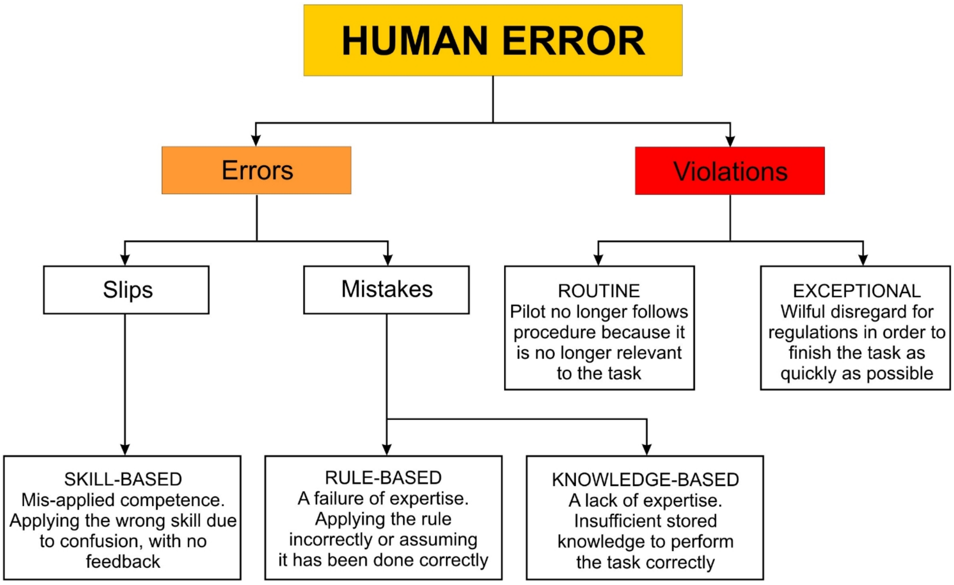


Figure 6.81

Human Error

Skill Based Errors

Skill based errors tend to occur at the initiation stage of any actions. There are three errors which are associated with skill based behaviour and decision making:

a. Action Slip. This occurs when a pilot makes the correct decision based on the situation, but exercises the wrong skill. An example would be to make the decision to raise the undercarriage but then raise the flaps by mistake. This could happen as a result of distraction resulting in no monitoring of the situation. The pilot will remain unaware of the mistake.

b. Environmental Capture. This is also known as habituation (becomes a habit). This is when our place in the "environment" leads to the error. Consider a session of circuits and landings. The instructor lets the student fly several normal approaches, and then instructs the student to carry out a flapless approach. On downwind, where the flaps are usually lowered, the student selects flap even thought the intention was not to do so. This has come about due to the environment even though the student had not made a decision to lower flaps. Another example is the call "Three greens" on finals, simply because the aircraft is on short finals and that no attention was given to the call, even if the lights may not be on.

c. Reversion. This when a pilot reverts the procedure he/she has learned best. This could occur if a pilot is flying in an aircraft that, although current on type, he/she does not fly on a regular basis. If confronted with an emergency situation the pilot may perform the corrective action that he/she is most familiar with even though it does not relate to the aircraft actually being flown at the time.

Rule Based Errors

Unlike skill based behaviour, which is stored as patterns of motor activity, rule based behaviour is stored as a set of rules in long-term memory. When activated, they tend to be monitored more carefully as the process develops. Errors in rule based behaviour are usually associated with an incorrect identification of the situation, resulting in the wrong procedure being selected. Occasions arise where a pilot feels it is safe to depart from laid down procedures.

Knowledge Based Errors

A risk associated with knowledge based behaviour is that of Confirmation Bias. This occurs when a decision has been made which as far as the person involved is the correct one, resulting in a tendency to overlook any information which fails to confirm the original decision. Conflicting data is overlooked. Even though several other sources confirm that the wrong decision has been made, there is a reluctance to change the original decision. It can also be described as "counting the hits, but ignoring the misses". A gambler will often brag about how much they have won, but rarely tell you how much the lost! An example in aviation is the graveyard spiral where the pilot has decided the loss of height indicated by the altimeter and the VSI is due to a low nose position, but does not check to confirm on the AH whether there is any bank involved.

Another form of knowledge based error would be the failure to respond to a warning horn or lights in accordance with the SOPs.

The memory of a previous event may influence the decision making process, even thought there might be slightly different indications. The preference for comfortable information, and simply a lack of knowledge could also give rise to error.

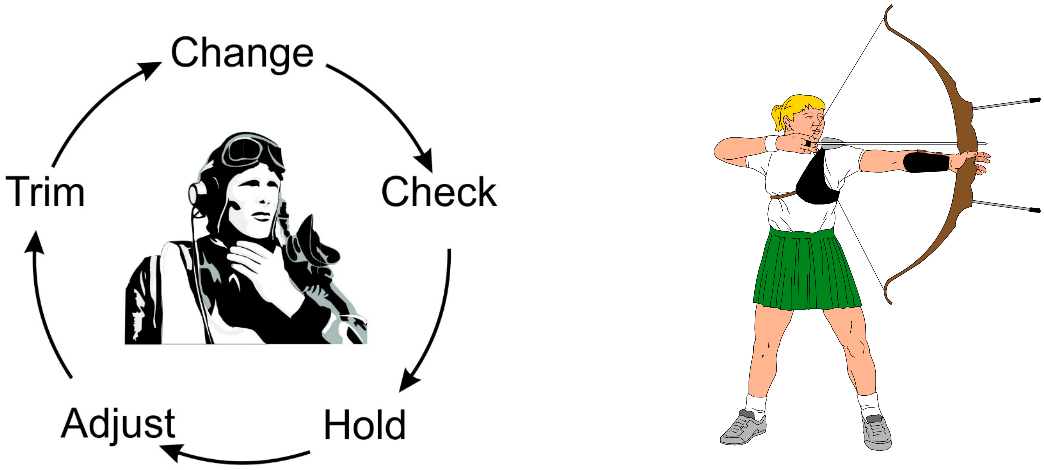


Figure 6.82

Closed Loop vs Open Loop System

As you build on your experience, you will find that the pilot and the aircraft form an important combination. Every time a control input is made, the aircraft will change attitude. This will result in changes to speed, height and direction, or combinations of any or all of them. Once the change is made, with proper monitoring, you can then see what correction is required, and make the necessary adjustments. You may have already heard the term, "Change, Check, Hold, Adjust and Trim". The combination of pilot and aircraft is known as a Closed-loop system which means that you have total control over where you want the aircraft to be. An open-loop system, by contrast, would be one in which you have no control over your initial action or input. Someone shooting an arrow from a bow, or a bullet from a gun, will have no control of the projectile once it leaves the bow or gun (see Figure 6.82).

Hazard and Risk

Two defining elements of decision making are hazard and risk. Hazard is a real or perceived condition, event, or circumstance that a pilot encounters. When faced with a hazard, the pilot makes an assessment of that hazard based upon various factors. The pilot assigns a value to the potential impact of the hazard, which qualifies the pilot's assessment of the hazard - risk.

Therefore, risk is an assessment of the single or cumulative hazard facing a pilot; however, different pilots see hazards differently. For example, the pilot arrives to preflight and discovers a small, blunt type nick in the leading edge at the middle of the aircraft's prop. Since the aircraft is parked on the tarmac, the nick was probably caused by another aircraft's prop wash blowing some type of debris into the propeller. The nick is the hazard (a present condition). The risk is prop fracture if the engine is operated with damage to a propellor blade.

The experienced pilot may see the nick as a low risk. He realizes this type of nick diffuses stress over a large area, is located in the strongest portion of the propeller, and based on experience, he doesn't expect it to enlarge the crack which can lead to high risk problems. He does not cancel his flight.

The inexperienced pilot may see the nick as a high risk factor because he is unsure of the affect the nick will have on the propellor's operation and he has been told that damage to a prop could cause a catastrophic failure. This assessment leads him to cancel his flight. Therefore, elements or factors affecting individuals are different and profoundly impact decision-making. These are called human factors and can transcend education, experience, health, physiological aspects, etc.

Another example of risk assessment was the flight of a Beechcraft King Air equipped with deicing and anti-icing equipment. The pilot deliberately flew into moderate to severe icing conditions while ducking under cloud cover. A careful pilot would assess the risk as high and beyond the capabilities of the aircraft, yet this pilot did the opposite. Why did the pilot take this action?

Past experience prompted the action. The pilot had successfully flown into these conditions repeatedly although the icing conditions were previously forecast 2,000 feet above the surface. This time, the conditions were forecast from the surface. Since the pilot was in a hurry and failed to factor in the difference between the forecast altitudes, he assigned a low risk to the hazard and took a chance. He and the passengers died from a poor risk assessment of the situation.

Hazardous Attitudes and Antidotes

Being fit to fly depends on more than just a pilot's physical condition and recent experience. For example, attitude will affect the quality of decisions. Attitude is a motivational predisposition to respond to people, situations, or events in a given manner. Studies have identified five hazardous attitudes that can interfere with the ability to make sound decisions and exercise authority properly: anti-authority, impulsivity, invulnerability, macho, and resignation. Hazardous attitudes contribute to poor pilot judgment but can be effectively counteracted by redirecting the hazardous attitude so that correct action can be taken. Recognition of hazardous thoughts is the first step toward neutralizing them. After recognising a thought as hazardous, the pilot should label it as hazardous, then state the corresponding antidote. Antidotes should be memorized for each of the hazardous attitudes so they automatically come to mind when needed:

Anti-Authority: "Don't tell me."
This attitude is found in people who do not like anyone telling them what to do. In a sense, they are saying, "No one can tell me what to do." They may be resentful of having someone tell them what to do, or may regard rules, regulations, and procedures as silly or unnecessary. However, it is always your prerogative to question authority if you feel it is in error.

Impulsivity: "Do it quickly."
This is the attitude of people who frequently feel the need to do something, anything, immediately. They do not stop to think about what they are about to do; they do not select the best alternative, and they do the first thing that comes to mind.

Invulnerability: "It won't happen to me."
Many people falsely believe that accidents happen to others, but never to them. They know accidents can happen, and they know that anyone can be affected. However, they never really feel or believe that they will be personally involved. Pilots who think this way are more likely to take chances and increase risk.

Macho: "I can do it."

Pilots who are always trying to prove that they are better than anyone else think, "I can do it - I'll show them." Pilots with this type of attitude will try to prove themselves by taking risks in order to impress others. While this pattern is thought to be a male characteristic, women are equally susceptible.

Resignation: "What's the use?"

Pilots who think, "What's the use?" do not see themselves as being able to make a great deal of difference in what happens to them. When things go well, the pilot is apt to think that it is good luck. When things go badly, the pilot may feel that someone is out to get me, or attribute it to bad luck. The pilot will leave the action to others, for better or worse. Sometimes, such pilots will even go along with unreasonable requests just to be a "nice guy."

Risk

During each flight, the single pilot makes many decisions under hazardous conditions. To fly safely, the pilot needs to assess the degree of risk and determine the best course of action to mitigate risk.

Assessing Risk

For the single pilot, assessing risk is not as simple as it sounds. For example, the pilot acts as his or her own quality control in making decisions. If a fatigued pilot who has flown 16 hours is asked if he or she is too tired to continue flying, the answer may be no. Most pilots are goal oriented and when asked to accept a flight, there is a tendency to deny personal limitations while adding weight to issues not germane to the mission. For example, pilots of helicopter emergency services (EMS) have been known (more than other groups) to make flight decisions that add significant weight to the patient's welfare. These pilots add weight to intangible factors (the patient in this case) and fail to appropriately quantify actual hazards such as fatigue or weather when making flight decisions. The single pilot who has no other crew member for consultation must wrestle with the intangible factors that draw one into a hazardous position. Therefore, he or she has a greater vulnerability than a full crew.

Figures released by the National Transportation Safety Board (NTSB in the USA) reports and other accident research can help a pilot learn to assess risk more effectively. For example, the accident rate during night VFR decreases by nearly 50 percent once a pilot obtains 100 hours, and continues to decrease until the 1,000 hour level. The data suggest that for the first 500 hours, pilots flying VFR at night might want to establish higher personal limitations than are required by the regulations and, if applicable, apply instrument flying skills in this environment. Several risk assessment models are available to assist in the process of assessing risk. The models, all taking slightly different approaches, seek a common goal of assessing risk in an objective manner. One is shown in Figure 6.83.

The most basic tool is the risk matrix. It assesses two items: the likelihood of an event occurring and the consequence of that event.

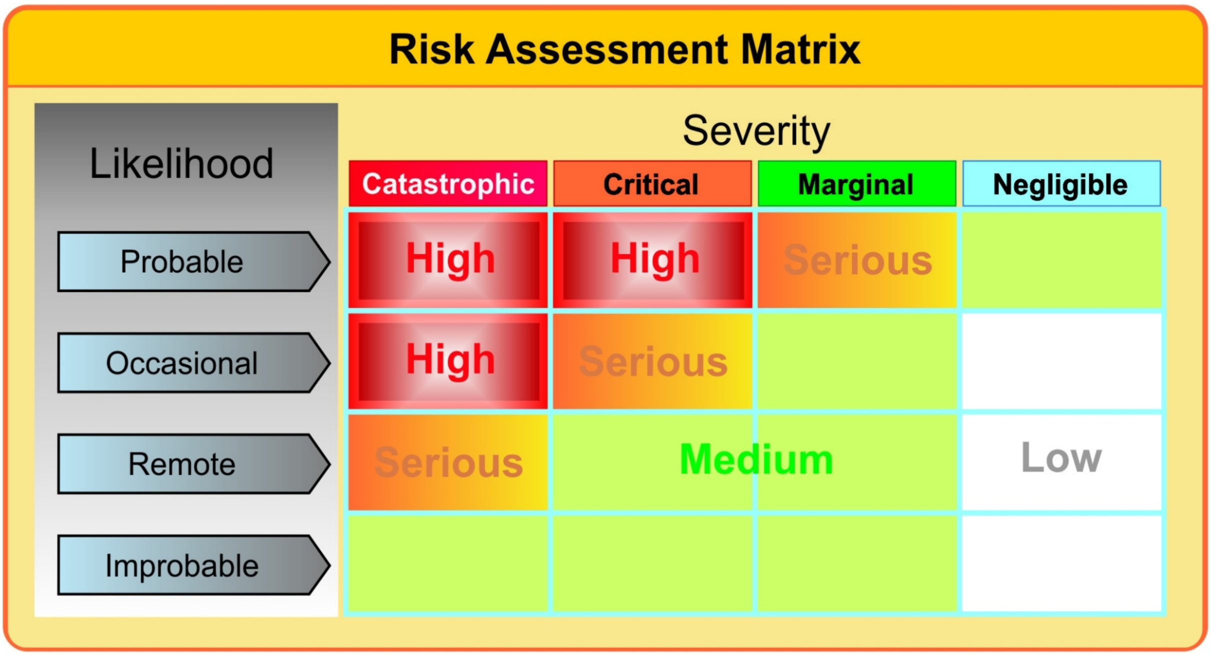


Figure 6.83

Risk Assessment

Likelihood of an Event

Likelihood is nothing more than taking a situation and determining the probability of its occurrence. It is rated as probable, occasional, remote, or improbable. For example, a pilot is flying from point A to point B (50 miles) in marginal visual flight rules conditions. The likelihood of encountering potential instrument meteorological conditions (IMC) is the first question the pilot needs to answer. The experiences of other pilots coupled with the forecast, might cause the pilot to assign "occasional" to determine the probability of encountering IMC.

The following are guidelines for making assignments.

- Probable - an event will occur several times.
- Occasional - an event will probably occur sometime.
- Remote - an event is unlikely to occur, but is possible.
- Improbable - an event is highly unlikely to occur.

Severity of an Event

The next element is the severity or consequence of a pilot's action(s). It can relate to injury and/or damage. If the individual in the example above is not an instrument flight rules (IFR) pilot, what are the consequences of him or her encountering inadvertent IMC conditions? In this case, because the pilot is not IFR rated, the consequences are catastrophic.

The following are guidelines for this assignment.

- Catastrophic - results in fatalities, total loss
- Critical - severe injury, major damage
- Marginal - minor injury, minor damage
- Negligible - less than minor injury, less than minor system damage

Simply connecting the two factors as shown in Figure 6.83 indicates the risk is high and the pilot must either not fly, or fly only after finding ways to mitigate, eliminate, or control the risk. In the example presented, a pilot assigned a likelihood of occasional and the severity as catastrophic. As can be seen from the matrix, this falls in the high risk area.

Although the matrix in Figure 6.83 provides a general viewpoint of a generic situation, a more comprehensive program needs to be made that is tailored to a pilot's flying.

This program includes a wide array of aviation related activities specific to the pilot and assesses health, fatigue, weather, capabilities, etc. Each is allocated a value. The scores are added and the overall score falls into various ranges, with the range representative of actions that a pilot imposes upon himself or herself.

Mitigating Risk

Risk assessment is only part of the equation. After determining the level of risk, the pilot needs to mitigate the risk. For example, the pilot flying from point A to point B (50 miles) in minimal VFR conditions has several ways to reduce risk:

- Wait for the weather to improve to good visual flight rules (VFR) conditions.
- Take a pilot who is certified as an IFR pilot.
- Delay the flight.
- Cancel the flight.
- Drive.

One of the best ways single pilots can alleviate risk is to make use the IMSAFE checklist to determine physical and mental readiness for flying. Ask yourself the following questions::

Illness - Am I sick? Illness is an obvious pilot risk.

Medication - Am I taking any medicines that might affect my judgment or make me drowsy?

Stress - Am I under psychological pressure from the job? Do I have money, health, or family problems? Stress causes concentration and performance problems. While the regulations list medical conditions that require grounding, stress is not among them. A pilot should consider the effects of stress on performance.

Alcohol - Have I been drinking within 8 hours? Within 24 hours? As little as one tot of liquor, one bottle of beer, or a glass of wine can impair flying skills. Alcohol also renders a pilot more susceptible to disorientation and hypoxia.

Fatigue - Am I tired and not adequately rested? Fatigue continues to be one of the most insidious hazards to flight safety, as it may not be apparent to a pilot until serious errors are made.

Eating - Have I eaten enough of the proper foods to keep adequately nourished during the entire flight?

If your answer is YES to the questions,
except for the last one,

DON'T FLY!

Situational Awareness

All of the preceding material contributes towards one major component of a successful flying career, whether professional or recreational. This means that you are able to maintain accurate mental models of your environment. In simple terms, where have I been, where am I now, and where will I be in a few moments time. Some people refer to it as being aware of the big picture.

Situational awareness involves being aware of what is happening around you so as to understand how your actions, based on your interpretation of events, will affect your goals and objectives. This must nor be seen as being something current, but also something that may affect you in the near future. The lack of, or having poor situational awareness has been identified as one of the primary causes of human error accidents. The most common types of aircraft accidents are CFIT (controlled flight into terrain) and loss of control in flight. In a CFIT accident, both the pilot and the aircraft are perfectly serviceable, yet something catastrophic goes wrong. Aviation places high demands on pilots, and poor decisions can have serious consequences. When situationally aware, you have an overview of the total operation and are not fixated on one perceived significant factor. Some of the elements inside the aircraft to be considered are the status of aircraft systems, you as the pilot, and passengers. In addition, an awareness of the environmental conditions of the flight, such as spatial orientation of the helicopter, and its relationship to terrain, traffic, weather, and airspace must be maintained.

A commonly used model to good situational awareness is one put forward by Dr Mica Endsely. This model identifies three steps in the development of good situational awareness: perception, comprehension and projection.

As mentioned earlier, our decision making process starts with perception. This involves constant monitoring of our environment, cue detection by the sensory stores, and the recognition of these cues. This makes us aware of the current situation (where am I?).

The next step, comprehension, involves interpretation and evaluation of this information in order to understand how it will all impact on your goals and objectives. This gives you an understanding of the world you are in, or at least that portion which is of concern to you as an individual (a better understanding of where am I).

Finally projection. This is the ability to project the future elements in the environment, and using this information to extrapolate forward in time to determine how my decisions will affect future states of the environment (where will I be soon?) .

To maintain situational awareness, all of the skills involved in aeronautical decision making are used. For example, an accurate perception of your fitness can be achieved through self-assessment and recognition of hazardous attitudes. A clear assessment of the status of navigation equipment can be obtained through workload management, and establishing a productive relationship with ATC can be accomplished by effective resource use.

Obstacles to Maintaining Situational Awareness

Fatigue, stress, and work overload can cause you to fixate on a single perceived important item rather than maintaining an overall awareness of the flight situation. A contributing factor in many accidents is a distraction that diverts the pilot’s attention from monitoring the instruments or scanning outside the aircraft. Many cockpit distractions begin as a minor problem, such as a gauge that is not reading correctly, but result in accidents as the pilot diverts attention to the perceived problem and neglects to properly control the aircraft.

Complacency presents another obstacle to maintaining situational awareness. When activities become routine, you may have a tendency to relax and not put as much effort into performance. Like fatigue, complacency reduces your effectiveness in the cockpit. However, complacency is harder to recognize than fatigue, since everything is perceived to be progressing smoothly.

There are a number of classic behavioural traps into which pilots have been known to fall. Pilots, particularly those with considerable experience, as a rule, always try to complete a flight as planned, please passengers, and meet schedules. The basic drive to meet or exceed goals can have an adverse effect on safety, and can impose an unrealistic assessment of piloting skills under stressful conditions. These tendencies ultimately may bring about practices that are dangerous and often illegal, and may lead to a mishap. You will develop awareness and learn to avoid many of these operational pitfalls through effective training.

Here are some of the operational pitfalls you need to avoid:

Peer Pressure - Poor decision making may be based upon an emotional response to peers, rather than evaluating a situation objectively.

Mind Set - A pilot displays mind set through an inability to recognize and cope with changes in a given situation.

“Get-There-Itis” - This disposition impairs pilot judgment through a fixation on the original goal or destination, combined with a disregard for any alternative course of action.

Scud Running - This occurs when a pilot tries to maintain visual contact with the terrain at low altitudes while instrument conditions exist.

Continuing Visual Flight Rules (VFR) into Instrument Conditions - Spatial disorientation or collision with ground/obstacles may occur when a pilot continues VFR into instrument conditions. This can be even more dangerous if the pilot is not instrument-rated or current.

Getting Behind the Aircraft - This pitfall can be caused by allowing events or the situation to control pilot actions. A constant state of surprise at what happens next may be exhibited when the pilot is getting behind the aircraft.

Loss of Positional or Situational Awareness - In extreme cases, when a pilot gets behind the aircraft, a loss of positional or situational awareness may result. The pilot may not know the aircraft's geographical location, or may be unable to recognise deteriorating circumstances.

Operating Without Adequate Fuel Reserves - Ignoring minimum fuel reserve requirements is generally the result of overconfidence, lack of flight planning, or disregarding applicable regulations.

Flying Outside the Envelope - The assumed high performance capability of a particular aircraft may cause a mistaken belief that it can meet the demands imposed by a pilot's overestimated flying skills.

Neglect of Flight Planning, Preflight Inspections, and Checklists - A pilot may rely on short- and long-term memory, regular flying skills, and familiar routes instead of established procedures and published checklists. This can be particularly true of experienced pilots.

Know your aircraft, know where it at all times, know the weather in which you are operating, and know the people you are working with. This will make you a safer pilot, rather than a “luckier” one, and your flying will become all the more enjoyable for it.

TYPICAL EXAMINATION QUESTIONS:

When taking any CAA test (or any test for that matter), keep the following in mind:

- Carefully read the instructions given with the test.

- Answer each question in accordance with the latest regulations and guidance publications.

- Read each question carefully before looking at the answer options. You should clearly understand the problem before attempting to solve it.

- After formulating an answer, determine which answer option corresponds with your answer. The answer you choose should completely resolve the problem.

- From the answer options given, it may appear that there is more than one possible answer; however, there is only one answer that is correct and complete. The other answers are either incomplete, erroneous, or derived from popular misconceptions.

- If a certain question is difficult for you, it is best to mark it for review and proceed to the next question. After you answer the less difficult questions, return to those you marked for review and answer them. Although the computer should alert you to the unanswered questions, make sure every question has an answer recorded. This procedure will enable you to use the available time to maximum advantage.

- When solving a calculation problem, select the answer that most closely matches your solution. The problem has been checked by various individuals using different methods of calculation; therefore, if you have solved it correctly, your answer will be closer to the correct answer than any of the other choices. Also when doing calculations, remember to any conversions that may be required so that you will be solving the problem using similar units throughout.

- Make sure you have all the equipment that you are permitted to take into the examination room with you when you arrive. This includes your CX-2 Pathfinder, the E6B Whizzwheel, and a calculator that is non-programmable. Also have a ruler, protractor, dividers, pair of compasses, and a pen/pencil handy. You never know what you may need, so come prepared.

In Human Performance and Limitations there are only a few questions involving numbers. None of them are calculations, but are rather known values from the text. Here are some examples, the first one being a “number” orientated questions:

The "time of useful consciousness" at 25 000 ft following rapid decompression is approximately:

a. 5 minutes,
b. 60 seconds
c. 15 seconds
d. 2 - 3 minutes

Answer and explanation:

Time of useful consciousness ids the expected time that a pilot will be able to perform normal actions after being disconnected from a source of sufficient oxygen before he/she is no longer capable of performing his/her duties as a pilot due to loss of consciousness.

Most of the questions in this subject will be based on theoretical fact, here is an example:

Select the, "Hazardous Attitude," that can be inherent in people who do not like to be told what to do.

a. Impulsivity.
b. Anti-authority.
c. Resignation.
d. Macho.

Answer and explanation:

Hazardous Attitudes

Anti-authority: "Don't tell me' This hazardous attitude is found in someone who does not like to be told what to do. They may either be resentful of having someone tell them what to do or may just disregard rules and procedures. An assertive person will question authority if warranted.

Impulsivity: "Do something quickly' Someone who does not stop and think about what they are about to do. They do not select the best alternative, they do the first thing that comes to mind.

Invulnerability: "It won't happen to me' Many people feel that accidents will happen to others but not to them. People who act this way are more likely to be risk takers beyond acceptable levels.

Macho: "I can do it" People who are always trying to prove themselves take risks to try and impress others. Both men and women are susceptible.

Resignation: "What's the use' People who have this hazardous attitude do not see themselves as malting a great deal of difference in what happens to them. They attribute events to either good or bad luck; they leave actions to others. They can go along with unreasonable requests to be a "nice-guy.'

The third type of question relates to the practical application of facts:

When conducting a flight, stress

a. is not desirable and should be avoided.
b. can be good to promote peak performance.
c. will always impair a pilot's judgment.
d. will restrict the amount of adrenaline produced by the body.

Answer and explanation:

Not all stress is bad. Boredom or over-stimulation have the potential to increase the rate of human error. Pilots require some stress to maintain peak performance. Stress levels change from day to day, from individual to individual. An awareness of what our stress levels are, and a lookout for an indication of what other crew member's stress levels are, will provide an indication of what performance level can be anticipated.

Now with this in mind, try the following using the processes described in the preceding questions:

1. A method for equalizing the pressure in the ears is called

a. the Bernoulli technique.
b. the Heimlich manoeuvre.
c. the Valsalva manoeuvre.
d. a decompression technique.

2. When taking an over-the-counter cough medicine, that you are concerned may have adverse effects on your performance, you should

a. read the bottle to see if it is still OK to act as a flight crew member.
b. plan not to act as a crew member, except on the advice of an Aviation Medical Examiner.
c. allow 8 hours to pass before acting as a crew member.
d. not act as a crew member at altitudes in excess of 8000 feet for 12 hours.

3. Tolerance to the effects of excessive G forces is reduced by

a. obesity.
b. poor health.
c. hangovers.
d. all of the above.

4. The first noticeable symptom of excessive positive Gs is

a. a very sharp head ache.
b. deterioration in vision.
c. euphoria.
d. light headedness.

5. It is important to employ an effective scanning technique when looking for other traffic. This can be accomplished by

a. constantly moving the eyes back and forth over the horizon.
b. using the "empty-field myopia" technique.
c. scanning only where traffic has been reported.
d. scanning areas of the sky in sections, briefly focussing on distant objects.

6. From below, select a good example of physical stress.

a. The continued vibration produced by the engines of an aircraft.
b. Lack of physical fitness.
c. Improper eating habits.
d. Difficulty solving a navigational problem during a cross country flight.

7. What is a good method for reducing stress?

a. exercise.
b. smoking.
c. sleep deprivation.
d. all of the above.

8. A pilot who smokes

a. is more susceptible to hypoxia.
b. is less susceptible to hypoxia.
c. is more susceptible to hyperventilation.
d. must use supplemental oxygen at altitudes in excess of 8,000 feet ASL.

9. From below, select a skill for maintaining situational awareness.

a. Communication.
b. Experience and training.
c. Spatial orientation.
d. All of the above.

10. Pilots should be most concerned with causing ear damage when

A. conducting steep climbs.
B. descending.
C. oxygen is not available.
D. pregnant women are on board.

The following questions do not offer any answer options. There may be more than one correct answer, so use your knowledge and the Meteorology text to find possible solutions.

1. A decrease in the amount of haemoglobin in the red blood cells leads to a condition called:

2. The volume of oxygen in the atmosphere is approximately:

3. Blood is pumped around the body by the:

4. Oxygen rich blood:

5. The pumping or discharge chambers of the heart are:

6. When measuring blood pressure the lowest reading obtained is referred to as:

7. A person suffering from sustained low blood pressure may experience:

8. In terms of the Gas laws, Dalton's Law states that:-

9. A pilot's susceptibility to hypoxia:

10. Hypoxic hypoxia occurs as a result of:

11. The amount of light which enters the eye is controlled by the:

12. In order to correct long sightedness, (hypermetropia):

13. With reference to the eye, the rods:

14. Vision in low levels of illumination or at night is dependant upon:

15. Control over the light entering the eye is exercised by the:

16. Good night vision is best achieved by:

17. In order to correct short sightedness, (myopia):

18. Memory which deals with the storage of information in word form is called:

19. Accommodation is the ability of the eye:

20. During the approach to land on an unfamiliar upward sloping runway a pilot may have a tendency to:

21. During the approach to land on a very wide unfamiliar runway a pilot may have a tendency to:

22. The vestibular apparatus comprises the:

23. Presbycusis is the term used to define:

24. If a passenger is observed suffering from mild chest pains, dizziness, breathlessness and a pale complexion the cause is likely to be:

25. The symptoms of low blood glucose (blood sugar), include a sensation of dizziness and shaking. This can be corrected:

26. Acute fatigue:

27. Chronic fatigue:

28. Sleep management is an important part of personal fitness and the type of sleep associated with physical rejuvenation is called:

29. The type of sleep associated with brain rejuvenation is called:

30. The most common symptoms of carbon monoxide poisoning are:

ANSWERS:

1	2	3	4	5	6	7	8	9	10
C	B	D	B	D	A	A	A	D	B

ANSWERS EXPLAINED:

1. The Valsalva manoeuvre is a technique used for equalizing pressure in the ears when swallowing or yawning is not effective. It is accomplished by: holding the nose and mouth shut and gently, but firmly attempting to exhale.

2. Simple over-the-counter cold remedies, antihistamines, laxatives, etc., may seriously impair the judgment and coordination needed by a pilot. One should not fly under the influence of prescription medication unless cleared by an aviation medical examiner.

3. G is the symbol for the rate of change of velocity and so represents both a force and a direction. Convention requires an indication whether a force is positive (+) or negative (-). For example, acceleration from the feet to the head is positive Gs and from the head to the feet is negative Gs. The effect of acceleration on the body is due to the displacement of blood and tissues.

   G tolerance varies greatly with the individual. Because the symptoms are caused by the displacement of blood and tissues, a pilot with good muscle tone will have a better tolerance. Tolerance is lowered by obesity, ill health, low blood pressure, pregnancy and many medications. It may vary from day to day in relation to fatigue, smoking, hypoxia or hangovers.

4. The most serious effect of positive G is to drain blood away from the head toward the feet, causing (stagnant) hypoxia of the brain, the first symptom being deterioration in vision. Vision, beginning in the periphery, starts to become dim and colourless; this is called "grey-out:' As the G forces increase further, the blood flow in the back of the eye will be completely interrupted and "black-out' (temporary loss of vision) will occur although the pilot is still conscious. There is a delay of 5-7 seconds between the onset of G and the visual changes because of the oxygen dissolved in the fluids of the eyeball. If G forces stabilize, there may be an improvement in the visual symptoms after 10- 1 2 seconds because the body's reflexes automatically increase blood pressure.

5. Completing a good visual scan is a practiced technique. It is important to take an object on the horizon, focus on it and then scan other sectors of the sky. It is a good idea to imagine the windshield broken into sections that you can individually scan, one at a time. It is important to occasionally focus on an object in the distance to avoid "empty-field myopia" (space blindness), which is the result of gazing at a featureless sky.

6. Related to humans, the term stress is used to describe the body's response to demands placed on it. There are three types of stress:

   a. Physical - environmental conditions, noise, vibration, stages of hypoxia;
   b. Physiological - fatigue, lack of physical fitness, improper eating habits; and
   c. Emotional - social and emotional factors related to living and intellectual activities, such as solving difficult problems in flight.

7. Stress, causes an unnecessary expenditure of energy through adrenaline production. The best way to rid the body of excess adrenaline is with physical exertion, or exercise. When it is not possible to exercise, a walk is a good way to relieve the effects of high stress, and also provides a mental time-out from the stressor. Vitamin C also helps rid your body of adrenaline.

8. Carbon Monoxide is a colourless, odourless, tasteless gas which is a product of incomplete combustion. Haemoglobin. the oxygen carrying chemical in the blood, picks up carbon Monoxide 210 times more readily than it picks up oxygen. Thus, even minute quantities in the cockpit often from improperly vented exhaust fumes, may result in pilot incapacitation.

The symptoms of carbon monoxide poisoning is insidious. Initially, there is an inability to concentrate, thinking becomes blurred, and subsequent dizziness and headache develop. If any of' these symptoms are noticed pilots should turn off the heater, open the air vents, and if safe, descend to a lower altitude. If oxygen is available, this should be used. If an exhaust leak is suspected the aircraft should be landed as soon as practicable.

Cigarette smoking is another source of carbon monoxide. Heavy smokers have 4 to 8%, of their haemoglobin saturated by carbon monoxide. This reduces the Oxygen carrying capacity of the blood and they may become hypoxic at altitudes below 10,000 feet ASL.

9. Situational Awareness, is defined as the accurate perception of the factors and conditions that affect an aircraft and its flight crew during a defined period of time. The following are skill for maintaining situational awareness:

- Workload Management;
- Communication;
- Spatial Orientation;
- Leadership and Teamwork;
- Managing Stress and Fatigue;
- Experience and training;
- Decision Making; and
- Flying Skills.

10. During climbs the air trapped in one’s middle ear is generally able to escape. However, when descending increased ambient air pressure can force the eardrum inward and can lead to severe pain and/or injury.

Answers to the straight questions - remember that these are not necessarily the only correct answers to each of them, but those given are all correct ones:

1. anaemia

2. 21%

3. left ventricle of the heart.

4. is bright red in colour,

5. the left ventricle and the right ventricle

6. the diastolic pressure

7. dizziness or fainting,

8. the total pressure of the gas mixture is equal to the sum of its partial pressures

9. increases with the consumption of alcohol, drugs and tobacco

10. an insufficient partial pressure of oxygen

11. iris

12. a convex lens is used

13. are used for peripheral vision

14. the rods

15. iris which expands increasing the size of the pupil

16. looking to the side of the object in order to focus the object on the rods

17. a concave lens is used

18. semantic memory

19. change the curvature of the lens in order to focus on an object

20. fly a low approach

21. fly a high approach

22. semi-circular canals and the otolith organs

23. a decrease in hearing ability with age

24. an angina attack

25. by eating regularly

26. is best treated by a peaceful, and uninterrupted sleep

27. occurs over a very long period and requires a prolonged recovery period

28. slow wave sleep

29. rapid eye movement (REM) sleep

30. headaches and nausea