Gliding New Zealand
Human Factors Syllabus for the Qualified Glider Pilot examination

Contents

1) Introduction
- evolution
2) Personality and the brain
- the perfect pilot
- airmanship
- the learning process
3) CRM, cross-cockpit authority gradient
4) Orientation and disorientation
- vision
- Illusions
- vestibular system
- disorientation (and motion sickness)
- IF
5) Altitude and its effects. The respiratory system
- the atmosphere
- trapped gases
- the respiratory system
- oxygen theory and usage
- hyperventilation
- decompression sickness (DCS or 'the bends')
6) Cardiovascular system
- 'g'
7) Hearing
8) The Gliding environment
- hypothermia
- heat stress
9) Fitness to fly/act as pilot-in-command
- AM I SAFE?
- illness and medication
- alcohol and drugs
10) Passenger flying.
11) Emergencies
- parachutes
- Survival, immediate and longer term

Conclusion
Appendices 1 to 8
Mock Exam

Jonathan Pote, Auckland Aviation Sports Club, May 2013 jonpote@hotmail.com

HUMAN FACTORS SYLLABUS FOR THE GLIDING NEW ZEALAND QUALIFIED GLIDER PILOT EXAMINATIONS

Jonathan Pote, MRCGP, Intermediate Certificate of Aviation Medicine, Royal Auxiliary Air Force (Retired)
QGP, Auckland Aviation Sports Club Gliding Section

1) INTRODUCTION

> *"There have been joys too great to be described in words, and there have been griefs upon which I have not dared to dwell; and with these in mind I say: Climb if you will, but remember that courage and strength are nought without prudence, and that a momentary negligence may destroy the happiness of a lifetime. Do nothing in haste; look well to each step; and from the beginning think what may be the end".*
>
> Edward Whymper, *Scrambles Amongst the Alps*

These are the words of Edward Whymper (1840 – 1911). What he said of mountaineering could very well apply to gliding with minimal rewriting. He was the first to conquer the Matterhorn (in the European Alps) in 1865; on the descent, four of the party fell and died. Had Whymper lived in our times, he would surely have been a glider pilot.

Again;
"Aviation in itself is not inherently dangerous but to an even greater degree than the sea it is terribly unforgiving of any carelessness, incapacity or neglect"
(Captain AG Lamplugh, an aviation insurance specialist of the 1930s).

The content that follows may seem excessive for a student glider pilot. The important matter is in bold type, but ideally the whole document should be read and understood; the cause of 75% of aviation accidents is contained within this text. Revision can be restricted to the bold type, which contains all of the answers to the multiple choice questions in the exam. The appendices referred can be found at the end of this document and are essential to overall understanding of the subject.

Aviation medicine and "Human Factors" may seem complex and irrelevant to gliding but nothing could be more incorrect. Whilst you are learning to glide, under the watchful eye of an instructor even when solo, little of what follows will be apparent. You may experience nausea or a little positive 'g' but not a lot more. The time comes when you proudly earn you QGP certificate and burst out of the 'training tunnel' to become an independent pilot. Perhaps you mistakenly thing you are ready for anything, but in reality the structured progress of the 'training tunnel' has to be followed by 'learning on the job' for as long as you glide. There will be surprises, but hopefully fewer if you study this text well. Once you are into cross-country and competition flying, as I hope you will be, the boundaries start getting pushed**. Sadly, incidents occur regularly, and there is on average about one fatality a year amongst the about eight hundred glider pilots in this country. In a very high percentage of the events, Human Factors play a part, and in well over half it is the major factor.** Almost all gliders are fully serviceable up to the point of impact and the weather is such that other pilots are flying that day in complete safety. It is with that pilot that the cause lies. One should not use the word “blame”, for it is neither deliberate nor (usually) reckless. Sadly, human factors have successfully set a trap for the unwary. Hopefully what follows will make you wary enough not to fall into such traps. Design, maintenance, meteorological forecasting and all other factors related to safety are improving, yet the accident rate is rising. **Glider pilots must continue to show themselves to be a responsible group of pilots who can be trusted to keep themselves safe in the air and a good knowledge of Human Factors is essential to achieving this.**

‘Human Factors’ comprises three sections, namely aviation medicine, aviation psychology and ergonomics (or the human/machine interface). Of these, aviation medicine looks at the physical functioning of the healthy body (with a brief look at those illnesses or diseases that affect flying ability) whilst aviation psychology looks at the function of the NORMAL mind and its function in the alien environment of flight. There is a tendency to think of psychology as covering the abnormal (“you need to see a psychologist....”) but the word literally means ‘study of the (normal) mind’. The abnormal mind is covered by psychiatry, which has no place in this document.

To write this document I have drawn on over twenty years as a medical officer in the RAF, both full and part time, and the formal aviation medicine training available to me in that capacity. However, I have learnt a great deal more from personal experience, and from talking to others, usually over a beer but at times over a strong coffee whilst debriefing a pilot after a close call or actual ‘event’. Human factors have a habit of jumping out at you just at the wrong moment; on three occasions I have had a close shave with disorientation. On two of those occasions, fully trained military pilots came extremely close to causing a non-survivable crash with me on board. On the third I had my hands firmly on the ejection seat handle in a BAE Hawk that I was convinced was about to crash; only instrument training (and, crucially, believing the instruments) saved me from ejecting onto a snow covered Welsh mountainside.

You will find the contents of this document fascinating even if in places complex. There is repetition but repetition is an excellent way of learning. Human Factors is not a subject to learn by rote; rather it is a subject to understand and to experience in your flying. Whilst doing aerobatics, for example, think about what your body is undergoing with the changing ‘g’ forces and revolving horizon. In a spin, thinking about more than just a safe recovery is difficult, but it is worth the extra sortie, especially when at QGP level and looking to further expand horizons, to sit passively through a spin entry and recovery by an instructor and note the sensations. There are aerodynamic events to observe and learn from too.

The evolution of mankind

As with all species, humans have evolved in order to survive efficiently in a certain environment. That environment was the plains of East Africa some six thousand feet above sea level, where pre-humans were hunter gatherers, largely by day. **Thus we have eyes which are very good at orientating us in our surroundings and sensing movement around us; movement that could warn us of danger or show us food. In poorer light, the inner ear gave confirmatory information about orientation. <u>Proprioceptors</u> (position, pressure and stretch-sensing nerve endings, located around our joints and in our skin) inform the brain and told us the position of our limbs if we could not see them clearly.** We were unable to experience significant linear or angular acceleration as we were physically unable to exceed running speed or to change direction very rapidly. Our environment was always a one 'g' environment on the ground; it was not the gliding environment we now enjoy. Only six generations ago, the Industrial Revolution had yet to happen and horse riding was the ultimate experience. Now humans successfully fly in fast jets at speeds up to a thousand miles an hour, at up to ten 'g', and climb to 100,000'.

All of the information received by the brain of early man via the senses contributed to one picture, a picture usually without contradictions or conflict. Thus the brain was able to relegate this function to levels well below consciousness **and leave the higher centres clear for thinking or decision making.** It is interesting how electronics has mirrored the brain in this, with the same disadvantages. Early radars gave an unprocessed image derived directly from the radar returns received by the aerial. This was a fuzzy black and white image looking like broken stratus cloud at night, and it took great skill to interpret it correctly. One method was to lay an acetate sheet with an outline of the area to the correct scale on it and find the 'best fit' before relying on the image to navigate the aircraft. This worked well most of the time, especially where coasts gave good outlines. Modern processed radars do away with this skilful input by the operator and give a perfect outline complete with spot heights, place names, airspace limitations and so on. This is excellent and requires less skill to interpret, but occasionally is totally wrong; the radar 'brain' has chosen the wrong area as the 'best fit'**. The brain sometimes does this, the result being an illusion. Illusions figure prominently in accidents and therefore in this text, but if you are aware of the possible illusions (landing on sloping strips for example) they are more easily avoided.**

Never forget that man was never intended to fly, but that very fact is what makes it so much fun: **"The danger? But danger is one of the attractions of flight".** So said Jean Conneau after his team mate was fatally injured flying in the 1911 'Circuit of Europe'. Jean himself died of natural causes many years later.

2) PERSONALITY AND THE BRAIN IN GLIDING

<u>The ideal pilot</u> No doubt we would all like to be – and many of us think we are – the Perfect Pilot**.** But are we?

To quote the late Ross Ewing, a widely respected Kiwi pilot and aviation physician, **"In addition to flying skills there are other attributes of the perfect pilot that can be learned and developed. Such attributes are seen in a pilot who is consistent, dependable, flexible, safe, knowledgeable, who**

flies accurately, who never flies dangerously, is confident but not overconfident, who can be relied to fly the aeroplane well, to make good decisions, to do the job and to keep out of trouble. A perfect pilot is someone who learns by experience and by the experiences of others, and who knows his or her capabilities and never exceeds them. A perfect pilot is one who always tries to improve his or her piloting knowledge and skills, and endeavours to know and achieve the highest standards in aviation. Perfect pilots will always set a good example, especially to those less experienced and will often go out of their way to assist other pilots to achieve higher standards and aim for perfection."

That may seem a lot to aim for, but it is not. Note that experience per se is not the sole answer to good flying; an inexperienced pilot can be a very good pilot (and inexperienced pilots become experienced over time) whilst a person who is a bad pilot at the outset will almost never become a good one. **The key to success is our mental ATTITUDE. Fly safely, always attempting to learn and improve.**

Safety Culture Risk is inherent to all flying, and gliding is no exemption, especially when pilots advance to competition flying. The key attitude is to **continuously assess risks, seek ways to reduce them, and assess whether the potential results justify the risk.** All glider pilots have the responsibility to try to improve safety. For example, only one person can initiate a launch (the wing runner, once they have ascertained that both tow and glider pilot are ready, and that it is safe to launch) but **everyone present has the duty to watch out for unseen danger** and shout "stop" if necessary. It may seem a hard thing to do, but if one pilot is aware that another is taking undue risks, then the matter must be raised. This duty lies especially heavily on the shoulders of instructors, but if an accident eventually occurs, then all those who remained silent have some responsibility for it.

Airmanship **Good airmanship is the display of common sense, good aviation practice and high standards whilst in the air *and on the ground* whilst at a gliding field. It includes the ability to cope when things are not as planned and being able to think outside normal procedures if necessary. Whilst a person's knowledge should always be increasing, good airmanship can (and must) be displayed from day one.**

Human Information Processing The functioning of the brain is complex and poorly understood, but we humans like to think that we can evaluate information about our situation and come up with a correct course of action to follow in a way no other animal can. Certain concepts (short term memory, long term memory, switching and overload) help our understanding of how the brain functions.

The contents of the long term memory are vast, even when we age and think we have forgotten "everything". Conversely, the short term or working memory holds remarkably few facts, either of recent experience or recalled from the long term memory to assist the decision making process. Information is received from the senses (eyes, ears etc.), sorted by priority, compared to information retrieved from the long term memory, and a decision is made. Some of the new information may be retained by transfer to the long term memory, but much may be discarded immediately and completely.

It is also surprising to learn that the brain can only work towards one solution at a time, be it an action or a decision. That a person can achieve so many solutions seemingly at the same time is because the brain is very good at switching from one task to the next. Thus a trained pilot can scan the instruments of a blind flying panel whilst talking to air traffic control and deciding whether it is safe/not safe to continue with the approach, all in bad weather. However, he is reading just one instrument at a time, or talking, or listening, or deciding, all in rapid sequence. As an illustration, sit in the cockpit and ask a friend to give you a new radio frequency and different barometric pressure. Try switching the radio to that frequency whilst at the same time adjusting the subscale on the altimeter to the new barometric pressure. This is extremely difficult (if not impossible) to do even in an unpressured situation on the ground. Nevertheless, several sequential actions are at times necessary in the air; for example, on approaching controlled airspace and contacting the controller, you may be given a new QNH to set, a specific 'squawk' to set, a course to set, a place to report and so on. Air Traffic Controllers are trained to give information in 'digestible chunks' of (usually) three items at a time but you can help yourself immensely by being ready to add figures to a pre-prepared kneepad with subjects (squawk etc) already marked in permanent (vivid) script and by already knowing as many details (e.g. frequencies, reporting points etc) as possible from your pre-flight self brief.

The Learning Process The solution as to how it is possible to fly a glider, or undertake any fairly complex activity, is by learning through repetition. When starting to learn to glide, each landing involves concentrating on flaring whilst keeping a straight course, perhaps with the into-wind wing slightly lowered (plus opposite rudder to compensate) and having to listen to the instructor! It seems impossible, but as time progresses, and the actions are repeated often, very probably with the instructor quietly taking care of some aspects initially, so you can concentrate on fewer inputs and it all becomes possible. The glider seems to have learnt to land itself. What has happened is that repetition and learning have moved many actions to 'lower centres' of the brain and they are now automatic responses rather than occupying your conscious mind, which is freed up for other decisions/actions. Thus in a land-out, once an experienced pilot has calculated his safe speed near the ground (always a conscious decision, weighing up the facts at the time) he probably barely thinks about it again, the glider seeming to know what speed to fly at whilst his conscious levels instead monitor the approach, continuously checking angles to the aiming point and look for new hazards. This is very different to an inexperienced student who might be 'chasing' a safe speed to the detriment of circuit pattern, lookout and a lot more.

Overload **If too much is asked of the conscious mind, it becomes overloaded and dumps not only decision making, but also some recently acquired information, often with poor prioritising.** Thus even information, such as a course to steer confirmed by readback, might be dumped rather than transferred to long term memory if some small crisis intervenes. Good instruction involves passing information to the student at a time when he has the spare capacity to receive and store it, not commenting on the circuit planning as he concentrates on the final approach and landing. An inexperienced person turning onto finals may cease to monitor airspeed in order to line up properly, despite knowing the vital importance of safe speed near the ground.

Standard operating procedures (SOPs) There are perhaps more 'SOPs' in gliding than you suspect, but the most prominent ones are the checklists; pre-takeoff, HASELL, pre-landing and so on. Even when they have become automatic it is very easy to omit items if there is a break in the sequence, either because someone interrupts us, or because something is found that requires action before continuing the list. **The only safe response is to start again,** even if there is time pressure such as the tug positioning in front of you to attach the rope. **If someone speaks to you and breaks your concentration, or you realise a harness strap is twisted and have to untwist it, start checks**

again at the beginning. Likewise, it is very poor airmanship for the wing-runner or any other person to interrupt a pilot during his checks. Wait patiently until the pilot has finished. Finally, once a checklist is complete, do not go back to an item. Having checked the undercarriage is down in your pre-landing checks, if you check again there is a fair chance you will actually raise it rather than make doubly sure it is locked down. This happens from time to time. **Remember the sequence used in each item of an individual check in a list: locate the item, identify, touch, confirm and operate it and finally check operation complete. In summary, LOOK; IDENTIFY; OPERATE.**

Stress and Stressors Stress may be defined as "the non-specific response of a human to any demands for change" or "an excess of environmental demands over an individual's capacity to meet them". That said, a degree of stress is not only normal, but necessary to get any useful output from a person. Some people thrive on stress and produce their best output when put to the test, whilst others crumble. **A good pilot will perform better under a degree of stress, but will not actively seek out stressful flying situations.** Likewise, one who does not tolerate stress well is not likely to cope well with an unexpected emergency.

Anything that causes stress is called a stressor. Gliding has **direct stressors such as air traffic control or navigational problems, temperature extremes, dehydration, hypoxia, disorientation, fatigue, visual illusions, weather, turbulence.** The list seems endless but learning to cope with these stressors builds our capabilities. **Indirect stressors are more insidious; this is the 'baggage' we may bring with us to the gliding field.** Such things as financial problems, relationship problems, fatigue from overwork and so on. Sadly these tend to be cumulative, and cannot be solved in flight as direct stressors may (such as when getting a definite position confirmation after being "temporarily unsure of position"). Indirect stressors also have a nasty habit of rearing their ugly heads at the worst moments ("This is going to be a tricky land-out, and with my current financial position I cannot afford to damage my glider ").

When going through the "AM I SAFE?" checks before flying (see section 9), be honest about your stress levels. Too many indirect stressors and you should not fly (although a pleasant day at the field, possibly with a dual flight, might be very helpful).

Stress and Fatigue management If there is too much stress in your life (ability compromised, not enhanced) then gliding should cease temporarily whilst you sort things out. Much has been said about stress management (and a commercial empire built on it) but in essence it is a matter of re-assessing work/life balance to set it more in favour of living and to prioritise your activities effectively. There is a famous saying that "life is what happens whilst you are planning to do something else", but you must somehow get things under control. This is easy to say, hard to do, but worth the effort. By **fatigue, I do not mean simple tiredness but a long term build up of stress** (see appendix 1). Neither damaging stress nor fatigue can be overcome quickly, certainly not on the day you intend to fly, so **do your 'AM I SAFE?' checks** (see section 9) **before you leave home, and plan accordingly. Once you arrive at the field, it is hard to be objective.**

3) CRM, and 'cross-cockpit authority gradient'

Over the last fifty years, the acronym 'CRM' (Crew Resource Management) has become a buzzword that sounds politically correct but of little use. Far from it. Many years ago, 'The Right Stuff' was typified by the bombastic, 'seen it all' pilot who could cope with any scrape whilst others cowered abjectly behind him. In 1972 Trident G-ARPI took off from London Heathrow captained by a Second World War veteran along with two junior pilots, both with brand new commercial pilots' licences. The Captain (who had just had an altercation over proposed strike action that he did not support) suffered a heart attack and was incapacitated. For all the cockpit alarms and obvious instrument readings, the two juniors (one of whom had full access to the controls, one only able to observe) did not take over control – He was The Captain, after all. The Trident entered a deep stall and crashed near Heathrow. There were no survivors amongst the one-hundred and eighteen on board even though there was no fire at first.

In 2008, a Boeing 777-200 G-YMMM of the same airline suffered an instantaneous simultaneous double engine failure at an altitude of 700 feet on approach into London Heathrow. The failure happened thirty seconds from touchdown with no warning and there were no options other than to make the runway or impact a built up area. The Captain, Peter Burkill, elected to leave his First Officer as the handling pilot to free up his own capacity to trouble shoot the situation (advantageous load shedding). All three pilots (the crew was augmented by an extra pilot due to the length of the flight) discussed the effects of reducing the flap setting (initial sink versus improved glide angle) and the Captain made the selection approximately seven seconds after the failure (rapid decision outside of normal procedures). The Captain then instructed the handling First Officer to complete the forced landing of the heavy jet on to grass while he continued to trouble shoot (maintaining free mental capacity). The reduced flap setting was instrumental in allowing the jet to clear the last obstacle, Hatton Cross tube station, by approximately twenty feet, saving the lives of all on board. The Multi Crew Cooperation (it's not called CRM any more in the airline industry as CRM places too much emphasis on the Captain) of the three pilots was the instrumental factor in preventing a far more serious accident.

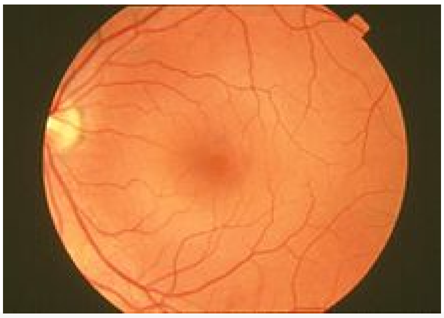
That is real progress in airline safety, but what is the relevance to gliding? **Those in two seat gliders must have that authority gradient, but the senior person must equally listen to his junior** who may have noticed a hazard unseen by the pilot -in-command. In the case of an instructor and pupil, there is no argument as to who is in charge even if not actually on the controls. However, consider two people of similar seniority where confusion may exist. In 2010, a glider crashed in New Zealand as each pilot left it to the other to start the engine when it became essential. On another occasion, two very experienced instructors (one giving the other a Biennial Flight Review) both thought the other was in his personal comfort zone in an extreme out-of-position tow exercise, but actually both were very unhappy. Luckily only a broken tow rope ensued, but it could have been a lot worse. A particular hazard concerns those have recently qualified as QGPs. It may be perfectly legal for them to fly together but **authorising instructors must clearly brief them as to who is in command** and perhaps politely suggest that they are not a suitable pair to fly together if he feels both are overconfident and likely to spur each other on.

4) ORIENTATION and DISORIENTATION

Vision

Adequate vision is of the utmost importance to all pilots but glider pilots are fortunate in that the standard deemed necessary for them is less than that for a powered pilot and equates to that deemed safe for a car driver. You must be able to read a car number plate at twenty-five metres, but do not need to pass colour vision tests. Having good sight alone is not enough; one must know how to use it effectively, understand its limitations, understand the situations in which it may let you down (visual illusions) and be aware of those factors that also intrude, such as hats, sunglasses and canopy design and clarity.

The eye and sight.



The blood vessels in a normal human retina. The optic disk is at extreme left in this photograph (same side as the nose), and the macula is near the centre. See in the second and fourth paragraphs below for details of the optic disc and the macula.

The eyes are effectively two spheres within the face which move and act in a co-ordinated manner (Appendix 2). Light enters these globes via the transparent cornea and the pupil (whose area varies by a factor of twenty-five, depending on light intensity). Most of the refraction occurs at the cornea, but further refraction and all focusing is done by the lens, its optical strength sub-consciously controlled by a muscle. **The image is focused on the spherical retina where receptive cells (cones and rods) convert light to nerve impulses, which travel via the optic nerve to the visual cortex at the rear of the brain. From here an image enters our consciousness. This relies heavily on adequate oxygenation of the eye and brain, and thus vision is affected early on by hypoxia (hypoxia is an inadequate amount of oxygen within the cells – see below in section 5).**

This simple scheme has many weaknesses, however. It is easy to think that the light image on the retina is as clear as that on camera film or digital sensor surface but this is not so. Not only is it inverted and laterally reversed, but the 'natural pixels' (rods and cones) are not on the surface of the retina but in a deeper layer. Blood vessels, the arteries and veins, are more superficial than the receptors and create gaps in that image**. The fine branches of the optic nerve come together at a point (the optic disc) on the inner (nasal) side of the retina before exiting towards the brain as the optic nerve. There are no rods or cones in this significant area, which is a few millimetres across,**

leading to a <u>'blind spot'</u> (of which we are normally unaware because the two blind spots are in different quadrants of the combined visual field and thus fill in for each other) in the upper outer quadrant of the visual field of each eye. Appendices 3 and 4 demonstrate the blind spot, and how **the brain fills in what it assumes is the missing information.** The illustrations are effective even on large scale diagrams; it is happening on a small scale throughout your visual field all the time. This becomes very dangerous when another glider is in the blind spot of one eye and hidden by a canopy arch from the other eye: you simply cannot see it.

Thus even in perfect conditions, it is a very ragged and incomplete 'file' that reaches the brain. **The brain processes this information to produce a sharp image with all of the gaps filled, based in large degree with what has been seen in the past, and what is *expected* to be seen now.** Modern radars do a very similar thing, resulting in a crisp clear coloured image of coasts etc. in place of the confused 'white on black haze' of older equipment. Sadly, both the radar (rarely) and **the brain (far more often) can get it wrong and confidently provide an entirely erroneous (and dangerously incorrect) image.** These visual errors and illusions can be hard to simulate in a teaching environment as one is expecting them, and, thus warned, the brain is not easily confused. It is very different when one is **tired after a long flight, suspicion dulled, and landing in an unfamiliar paddock** for example (see page 12).

<u>The visual process involving avoiding a mid-air collision.</u> **There are two types of receptor cells in the retina, RODS and CONES. The rods react to weaker light levels, are mainly in the periphery of the retina and cannot register colour, but are linked in a way that allows them to detect movement well. Thus when the rods register a possible threat 'in the corner of our eye', we turn automatically towards that sector and thus place the image in the centre of our visual field, on the <u>macula</u> (which is only a few millimetres across). Here most of the receptors are cones which require a greater light intensity but can detect objects in far greater detail and in colour. In the centre of the macula, on the visual axis, is a shallow cup (the fovea or 'pit') which increases the surface area of the retina locally and thus the number of cones that occupy this very small visual arc. This is where fine detail is registered, and indeed the fovea of a hawk is appreciably more deeply indented than ours giving better ('Hawkeye') detail. Once the image (of in this instance the other aircraft) is centred on the fovea, the brain receives a more detailed input and if the object is familiar, memory provides positive identification. If positive identification is not possible, the brain does its best from the available information and past experience. Often this 'guess' is good, but sometimes dangerously wrong. This input is now evaluated (threat or benefit?) and at last a response can be made. This takes time, and, even after control inputs are made, the glider itself takes more time to respond. It may be surprising (see appendix 5) to learn that from the time you first notice another glider it can be over seven seconds before you are taking effective action, i.e. your glider is manoeuvring to avoid collision. Clearly avoiding mid-air collisions by sight alone relies on a degree of luck however good your look out.** Two gliders with a combined closing speed of 120 knots will cover up to 500 metres in this time. If the other aircraft closing with you is a jet, up to a mile will have been covered in this seven seconds. The appearance of *Flarm, SeeYou* and other electronic aids is very timely for flight safety but can be a distraction from the **all important look out**.

<u>Scanning: The twenty degree/two second rule.</u> Whilst we might hope that our peripheral vision will alert us to dangers at the periphery, often this is not the case. It is necessary to look for other aircraft; you must actively scan. The area of good visual acuity (the macula) covers a mere 20 degree field. Thus to reliably scan an area we have to divide it into 20 degree segments and look at each for two seconds for an image to actually form within our consciousness. Clearly to cover the entire sphere around us takes impossibly long (several minutes) to be sensible, so certain areas have to be selected. **Ahead is obvious, but also look into turns before and whilst turning, look down during HASELL checks and so on**. Effective scanning is not quickly learnt but you have ideal opportunities to practice; when running the wing, check the circuit systematically from the down wind joining point to final approach properly (twenty degree arcs for two seconds) before you signal 'take up slack'. When gliders are in the air and you are on the ground, practice searching the sky systematically to pick them up. If they are up there and you cannot see them, or if others seem able to find them more quickly, you need to practice more. **Note how gliders seem to disappear and re-appear as they turn. It is just the same when you are flying, so a 'clear scan' of an area does not prove it is empty. Look again soon.**

<u>Empty Field myopia:</u> Somewhat surprisingly, at rest the eyes focus only a few metres away, not at infinity. This tends to occur when the visual field is uniform, such as when at high altitude with few clouds to focus on. Be aware of the problem and occasionally focus on a cloud, for example, during your scan. If nothing else is available, the wingtip is an option. After a look at the instruments, consciously refocus your eyes into the distance.

<u>Constant angle, constant danger:</u> We noted above that the rods are good at detecting relative movement and the eyes then look that way for better information**. If two aircraft, each flying straight, are on a collision course there is no relative movement. Even the apparent size of the image hardly increases until very close to impact. To avoid this danger, bank and turn a little, frequently. This makes you more visible to the other pilot, and his aircraft will move in your visual field; collision is far less likely.** Consider a gliding competition where the lift is poor but suddenly one glider finds a thermal and starts to circle. All other competitors are likely to head in straight lines to the thermal entry point below him, the perfect scenario for a collision. Weave a little as you approach that point. An interesting parallel occurs in driving, when two cars approach cross-roads at right angles. Sometimes neither notices the other and they either take action very late or actually collide. This explains some 'inexplicable collisions'; at least gliders have the third dimension to manoeuvre in.

<u>Hypoxia:</u> The visual system is very sensitive to even mild hypoxia (see page 22), colour vision reducing at around 6000'. Bear this in mind when you fly high

<u>Luminance:</u> The degree of brightness is important for the brain to register, which is why a bright red obstruction light is so much more effective than just a red painted object. There can also be too much luminance, or glare, and this reduces visual acuity. **Remember that at the end of the day, if landing towards the west, the sun in New Zealand can be very blinding – and may only appear below cloud as you get low.** Your eyes become fatigued just like any other part of your body. **Using sunglasses helps reduce this fatigue.**

Lasers: Lasers are increasingly (and of course illegally) being aimed at pilots, both military and commercial. There have been some examples of this in New Zealand. The victim would see a very bright, 'blinding' light from the ground very briefly. Sight is unlikely to be affected enough to present a hazard, but examination by an ophthalmologist afterwards would show a scar on the retina. Any such event should of course be reported via your CFI to GNZ, the NZCAA and the police, with an approximate idea of where (and when) the laser was fired.

Contrast: Henry Ford said his customers could have their Ford Model T in any colour they liked, provided it was black. It seems glider manufacturers will let you have gliders in any colour at all provided it is **white. Sadly this is the least contrasting colour of all in the sky** (perhaps surprisingly, black is the best contrast even in a dark sky, and all Royal Air Force training fast jets are black overall) but white is necessary as the composite material cannot withstand the heat absorbed by dark colours in strong sunlight. 'Camouflaged' gliders are a problem we have to live with although there are experiments afoot, such as painting the underside of the wings black. At least white gliders are easily visible after landouts. Cloud shadows can reduce contrast considerably. When you are flying, look at two similar areas, one sunlit, one in shade. Although you know both are similar, they look very different; detail is much worse in the shaded area. **As you fly along a ridge, if a spur ahead is in cloud shadow you may not see it until too late as there is little contrast to help you.**

Colour vision: Colour vision is not as important to glider pilots as it is to even powered recreational pilots let alone commercial pilots. There is no exclusion from any gliding activity due to colour vision defects or complete colour blindness but if you are affected, be aware that maps and instruments may be harder for you to read. This may influence the model of GPS or other aids you use; go for the brightest screen, add a sun visor and possibly use a black and white screen model for the glide computer etc.

Rain on the canopy: Flying in rain has its own aerodynamic problems of decreased glide angle, increased stalling speed etc. but also causes a visual problem. The rain drops stream backwards across the canopy, rising towards the rear in concert with the airflow and form a prominent image which partly obscures the view beyond the cockpit canopy. The eyes tend to focus on the near image of rain drops on the canopy and not the image of the landing area beyond. Only when below the normal roundout height may you notice how low you are, resulting in a rapid raising of the nose, perhaps too late to prevent a heavy landing. Thus **a landing with raindrops on the canopy is at increased risk and great care must be taken.** As an illustration, sit in a glider on the ground when the canopy is covered with large rain drops. The view out is not good, and it is worse when the slipstream is moving those drops. The same is true on the road if you are driving in rain without wipers, but do not try this.

Visual Environment: **Having considered all these details, let us come back to the obvious (although frequently ignored) basics. You will see better through a clean canopy, so carefully cleaning that should routinely accompany the DI. Sunglasses should be pristine (plus of wrap-around shape), and hats must have a brim that does not intrude into your field of vision.**

Illusions

Visual or Optical illusions are intriguing. It is well worth looking up 'Optical Illusions' in Wikipedia. Whilst in most cases they are not relevant to gliding, you will see how easily our brains are misled by visual input. **The exception is that of depth, the *Ponzo* illusion.**
www.en.wikipedia.org/wiki/Optical_illusions
Look at it and learn the lesson well.

<u>Depth perception illusions:</u> Surprisingly, we have binocular vision only to a distance of about four meters. Beyond that we estimate distance largely by comparison with familiar objects such as another aircraft, farm animals and so on. Trees and buildings are particular traps; there are numerous examples of aviation accidents or 'might have beens' caused by these traps. Perhaps you fly from a strip with many tall conifers close by. Apart from them causing turbulence, they are conditioning you to expect a certain visual image as you are in the circuit and on finals. If your first land-out is by chance into a field surrounded by 'Christmas trees' only three metres high, you may subconsciously try to achieve the same picture as at your home field. There is a very significant chance that your circuit will be both far too tight and too low (your altimeter is reading altitude, not height above ground). If you do manage to haul the glider around tightly enough to line up for finals (you will probably overshoot the centreline as you will not anticipate the tight turn required) you will be dangerously low with the problems of your long wing spanning wind shear in the turn. Very experienced pilots have been caught by this one and the only way to avoid it is to consciously seek all available information. Farm buildings can be treacherous – Is that a big barn or a small shed? Livestock is friendlier; as you learn to glide, when you have the reserve capacity to do so, look at the cows and sheep below you as you start your downwind leg. Note at what height you can see their legs clearly; you can trust your altimeter at your home strip as you set it recently for this very strip (remember that it is still altitude indicated, not height)**.** Tractors and cars are helpful standard sizes too. At all stages in the circuit, you should be relying on angles rather than constantly re-assessing heights.

<u>Approach illusions:</u> Gliding clubs operate from fairly level strips about fifty metres wide and eight-hundred metres long. To help you appreciate the illusions to be described, find a convenient object with about this aspect ratio of 1:16; a narrow 30 cm ruler should do nicely.
<u>Effect of up and down slope:</u> Hold the ruler level about 30 centimetres away and slightly below your line of sight so that it looks like a runway as you are on short finals. Without raising or lowering the near end of the ruler, rotate the ruler thirty degrees up at the far end. If you have done enough gliding to get a feel for the visual aspect when on approach, you should 'feel high on approach'. Now rotate the ruler thirty degrees down; you should feel 'low on approach'. And yet the threshold (near end of the ruler) is at a constant point below your line of vision. This effect reads over to gliding; on a runway sloping downwards into the distance, the tendency is to approach too high (you feel low, so raise your flight path). On up-sloping runways, the tendency is to be too low. These effects are exactly what you do not want: a late correction landing on a down-slope gives you extra speed whilst the landing run is going to be prolonged anyway whilst on an up-slope a late realisation that you are too low means less energy for the increased round-out angle necessary to hold off on the upslope. By approaching at a pre-determined and

accurately flown airspeed, using partial airbrake, a glider is within the bracket to be landed on an upslope as well as a (very slight) down slope. If the down slope is significant, this must be appreciated during field selection and either a different paddock selected or (if unavoidable) an up-slope, down wind landing made.

Effect of Runway length and width: As mentioned, runways for gliders and light aircraft tend to have an aspect ratio around 1:16 and as we learn to glide these proportions become the expected norm. However, if we operate then from very wide or very long strips, there is a tendency to get approach angles and thus heights wrong. When approaching very wide strips, the landing run available seems less than it actually is but extra runway length is not a problem. However, if the strip is very thin, it may seem longer that it really is until the far end hedge approaches at alarming speed and a ground loop may be your only option. That said, since the landing area should have been chosen from above at a safe height, this should not be unexpected unless a bad choice has been made before the approach began. Again, if interested, find yourself an appropriate set of 'runways' to hold in your hand and explore the effects of differing relative lengths and widths.

Effect of transverse slope: If a field slopes gently across the intended landing run (not ideal, but acceptable if there is no better alternative) then on the downwind leg with the paddock sloping downwards towards you, you may feel high as the angle of the ground to your position has been increased by the angle of the slope. If unaware of this effect, you may end up too low as you turn onto base leg.

False horizons in the mountains: Gliding training carried out in flattish surroundings will normally enjoy a good horizon for reference purposes. However, in mountainous areas the lack of a clearly defined horizon creates visual illusions that may tempt the pilot to raise the nose or to bank inappropriately. These tendencies must be eliminated early during training for safe ridge and mountain soaring.

The Vestibular (Balance) system

Orientation

Ancient man needed to be able to **orientate himself (where am I and what is happening to me and around me?)** whilst stationary on the ground or moving at up to about 25 KPH and accelerating to/decelerating from that speed over a minimum of a few second **WHILST ABLE TO SEE HIS SURROUNDINGS.** Running in the dark was not an option unless in mortal danger. Even flight in a glider takes you way outside those parameters in terms of speed, linear acceleration and above all rotation. Before considering the vestibular system of the inner ear, which is central to this problem (appendix 6 and below as well) you must be clear about some concepts:

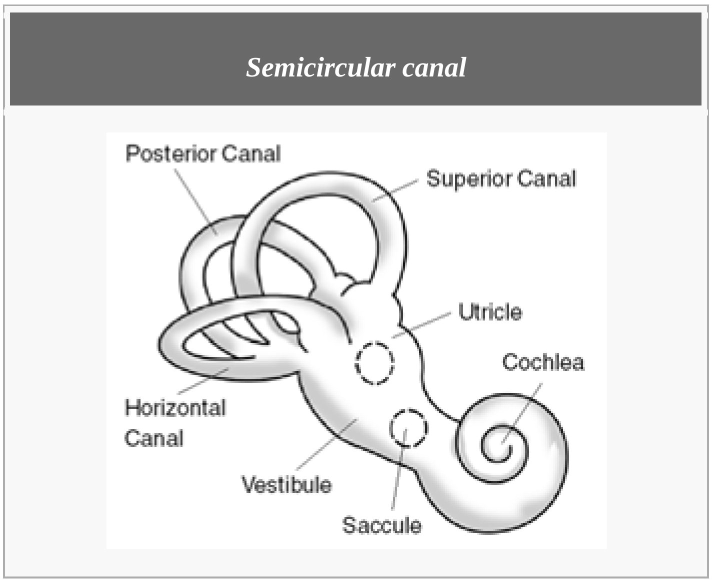
Static **implies no movement at all.**

Linear motion or acceleration **occurs in a straight line,** such as in level flight (linear motion) or a stable dive (linear acceleration). The transition phase from one to the other includes angular movement as well as linear movement.

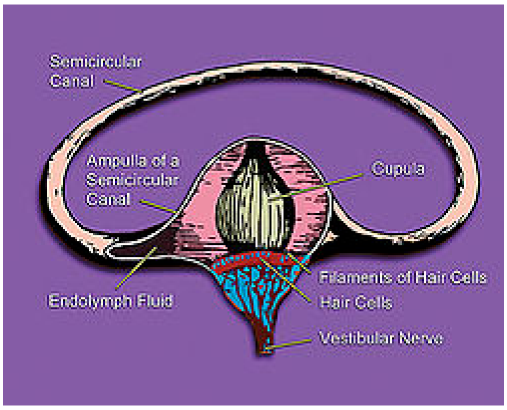
***Angular movement or rotation* implies that an object is changing direction or rotating at a constant rate.** The steadily moving second hand of an analogue clock is an example, as is a glider once established in a steady turn.
***Angular acceleration or deceleration* implies that the rate of rotation is increasing or decreasing.** A rotating weight hanging on a piece of rubber is an example – as the rubber twists and absorbs energy, so the weight progressively slows down until it stops momentarily, before reversing its direction and accelerating its rotation in the opposite direction. The same occurs at the other extreme after it has passed the mid-point of no twist. Likewise **in a glider, as a turn is entered, there is angular acceleration until a steady rate of turn is achieved, after which there is only angular movement. Exiting the turn requires angular acceleration in the opposite direction until nearly on the desired heading, when angular deceleration to zero angular movement steadies the heading.**

Orientation implies the person being (correctly) aware of their surroundings and of their position within those surroundings. The senses (vision, hearing, the vestibular apparatus of the inner ear and proprioception – the position sensor mechanism around joints and in muscles) provide this information both in static and moving contexts. **Vision is the primary source of information**, linking the image on the retina to previous knowledge to provide information about the surroundings. Proprioception, that is stretch receptors around the joints and pressure receptors in the skin (particularly in weight bearing areas such as the soles, palms and buttocks) provide information about the position of limbs etc., and how the person is supported. **In good light, the vestibular apparatus (balance sensors in the inner ear) merely provide confirmatory information which rarely conflicts with sight.**

The Vestibular system



<u>The vestibular system (See appendix 6 to relate this to the ear)</u> Note the three semicircular canals and the saccule and utricle (the latter two known together as the otolith organs). The cochlea is the organ of hearing.



A semi-circular canal schematically

The vestibular system is very complex but is able to sense both the static position of the head and ANGULAR ACCELERATION of the head.

The utricle and saccule are two small chambers (known collectively as the 'otolith organs') each sensing the static position of the head in one of the two planes equivalent to roll and pitch. They do so by having tiny sensory hairs topped with a crystal of bony substance, all enclosed in a jelly-like material which acts to dampen vibration. Thus **when the head leans to the left, so the weight of the bony crystals bends the sensory hairs and they lean further over to the left. The brain senses this as a head tilt to the left.** The same occurs in the fore and aft (pitching) plane, giving the feeling of the head being raised or lowered.
However, these crystals possess mass and therefore are 'left behind' temporarily if there is linear acceleration in either plane (although usually this occurs only fore and aft, not side to side). Whilst the input to the brain is identical in each case, it is short lived in the case of acceleration when we run (as we can only reach perhaps 20 kilometres an hour) or lean sideways. The visual input confirms events so that there is no confusion of static position with linear acceleration.

The semi-circular canals (which sense *angular acceleration*) are more complex. There are three in each vestibular apparatus, roughly at ninety degrees to each other and thus able to cover pitch, yaw and roll. Each canal (actually a tubular cavity within hard bone) is fluid filled and has a hinged membrane across the cavity at one point. Because the fluid has inertia, if the head (and thus the appropriate semi-circular canal) rotates in one of the planes, so the fluid will be temporarily left behind, flowing within the canal and deflecting the membrane. Soon, however, if the rotary motion continues at the same angular rate (degrees per second) both the friction at the fluid/bony interface and the partial obstruction due to the membrane will cause the fluid to 'catch up' and thus the membrane will return to its resting position EVEN ALTHOUGH THE ROTATION CONTINUES. The sensory hairs within the membrane thus only detect ANGULAR ACCELERATION (*degrees per second per second*) and not angular rotation (degrees per second). The orientation of the other two semi-circular canals means that no fluid movement will occur within them as their orientation is perpendicular to the rotation we are discussing.
The situation is further complicated. Unless the angular acceleration is confined exactly to the plane of just one semi-circular canal, there will actually be fluid movement to a greater or lesser

degree in two or even all three canals. This allows the brain to interpret angular acceleration in not just the primary yaw, pitch and roll planes but in combinations of all three. A second important fact is that the system has a threshold and can only detect angular accelerations of about two degrees per second per second or greater. A third complication is that all three canals communicate with each other. This configuration means that fluid movement within any two of the canals due to angular rotation in both of their planes can cause rapid fluid movement within the third canal even although there is no corresponding angular acceleration in that plane.

That is the system as it has evolved over the millennia, and it is very effective in ordinary life on the ground. As light levels drop, so vision is gradually superseded by the vestibular apparatus as the primary source of orientation information, but without conflict with remaining visual input. The proprioceptive input (body configuration and support) is independent of light levels and agrees with both sight and the vestibular information.
Thus if we are half way up a stepladder in a lightproof cellar when the bulb blows, there is no problem. The vestibular apparatus tells us that we are still upright and not moving, pressure receptors add that all our weight is on one foot, whilst joint position receptors confirm that one leg is straight whilst the other is bent, on a higher step and hardly weight bearing. Everything agrees, even the horizontal chink of light beside the trapdoor, and we confidently step down onto the floor and feel our way to the torch we wisely provided. Likewise, if we stand stationary and tilt our head to one side, the visual image shows the tilt compared to our field of vision whilst the saccule and utricle confirm that our head is tilted but the semicircular canals are not registering any angular acceleration. All is in harmony. Then we decide to run as fast as we can. Vision shows our surroundings changing as our position changes, and the saccule and utricle register horizontal (linear) acceleration for as long as it takes us to reach our lowly maximum speed of perhaps 20 KPH. There may be conflicting information as we lower our head to run, but stretch receptors around the neck plus vision confirm this has happened without confusing the brain**. All is well, until we fly in a glider and enter cloud.**

Disorientation (and Motion Sickness)

When starting to learn to fly, some people do feel slightly strange but quickly get accustomed to the sensations. The speeds and accelerations are much greater than on the ground, but the visual input explains those sensations and you adapt. The same occurs at sea; sea-sickness tends to abate after forty-eight hours, and people ‘get their sea legs’. They no longer stumble with the motion which, as in flying, can include pitch, roll and yaw even when largely in just two planes. This adaptation to flying is partly due to reduced apprehension as well as more attention directed outside by a student pilot as his training proceeds, and is why passenger flights should be conducted gently and in calm weather. **The occasional conflict between sight (say when the horizon is at thirty degrees, but being in a steady balanced turn the force [gravity plus angular movement] is vertically through the seat) is the basis of motion unease/sickness.** This susceptibility to motion sickness is lost over several flights, but returns when regular flying ceases for a few weeks – even experienced aerobatic pilots feel unwell when starting to practice at the start of a new season.

True disorientation is a large step beyond motion sickness, and essentially entails disbelief about what is being felt. It is essential to overcome this understandable disbelief to survive; the choice is as stark as that. Rely on your training or die. Many thousand pilots have died for this reason and continue to do so. In less than three thousand hours flying, I have had to sidestep the Grim Reaper of disorientation three times; it is not an uncommon experience. On each occasion the instruments told the true story even although it seemed very different to the pilots concerned.

Linear disorientation. This is usually not a problem for glider pilots as gliders cannot accelerate without descending, but consider a high performance aircraft taking off at night. Jet aircraft, especially the early ones, accelerated slowly on the runway, but increasingly once speed built up and they became airborne. Just at that moment they left the visual environment of the runway lights and plunged into darkness. The linear acceleration continued to bend the little hairs of the utricle and saccule backwards, and in concentrating on flying the aircraft they wrongly sensed the nose as rising and eased forward on the stick. The acceleration increased, and so the stick was pushed further forward until they impacted the ground. Literally hundreds of early jet pilot trainees died this way until the problem was properly understood and tackled in training. The reverse occurred in landing at night or in cloud; deceleration as flaps and undercarriage were lowered triggers a feeling of the nose being lowered, so instinctively it was raised – at a perilously low speed, leading to a stall on finals. This was less of a problem because the pilot was usually entering a corrective visual environment – seeing the runway lights or descending into clear air below cloud. **Occasionally glider pilots (especially those trained in aero tows behind less powerful tugs) being winch launched lower the nose inappropriately as the glider accelerates from standstill to about sixty knots very quickly whilst also rotating into the climb, usually with just a nasty surprise rather than a tragic outcome. Again, those little hairs with their weighted tips have been bent backwards due to the acceleration and their inertia, the brain interpreting this as the head looking steeply upwards rather than considerable horizontal acceleration with a slight raising of the line of sight. The instinctive reaction may be to lower the nose inappropriately in the belief that it has been raised excessively.**

Angular disorientation. This is the real killer
Consider this scenario; perhaps you fly into cloud. No problem, you think – I'll be in clear air again soon, and I can always turn 180 degrees on the compass, keeping the airspeed constant with elevator, and I'll soon be back where I was and just a little lower. But the then airspeed increases, and when you use 'up elevator' to reduce it, the speed increases even more (so does the pressure on your seat, but you expect that with 'up elevator'). What the hell is happening? You then lower the nose with elevator and speed increases even more. You are at VNE (the maximum safe speed of the glider) and accelerating. The glider might develop flutter and break up or you might exit the cloud vertically downwards in a spiral dive, lethally low. You have discovered the GRAVEYARD SPIRAL – and are about to join the tens of thousands of pilots who have been killed by it.
Another scenario is spinning. In training, usually the student is in control at the entry, knows which foot he pushed forward, and thus which foot to use for the recovery: "The other foot, stupid". It is therefore preferable, once the student is competent, for the instructor to initiate the spin, even for the student to close his eyes until told to open them and then for him to recover thus simulating spinning in cloud. **Accidental spins are different to intentional spins; if you are turning tightly in a thermal at minimum sink speed (just over the stall), a gust or sudden avoidance of another glider**

might precipitate an accidental spin. This is of course why we do spin training – to cater for the accidental spin. You did not use full rudder to enter the spin and hold the glider in the spin, so which is "the other foot"? Not a stupid question after all. Quite soon your semi-circular canals will have ceased to give you useful information because the fluid within them has 'caught up' with the canal structure. Likewise, whether you initiate correct recovery (apply full OPPOSITE RUDDER, then ease stick centrally forward until spinning stops, centralise rudder, roll wings level with aileron and ease out of the ensuing dive), the fluid in your semi-circular canals continues to move and now gives the sensation of turning THE OTHER WAY. It is not unknown in accidental spins for the pilot to reverse direction of the spin rather than recover due to this conflicting information of eyes verses vestibular system input or to use pro-spin rudder and enter a spiral dive. Two more easy ways to die.

The Coriolis effect. It was noted above that **movement in two planes will not only cause fluid movement in the appropriate two semi-circular canals, but possibly greater movement in the third canal even although there is no actual movement of the head in this plane, and thus no corresponding visual input to the brain. This gross mismatch of visual image and vestibular sensation causes a most unpleasant tumbling feeling frequently accompanied by feelings of motion sickness or actual vomiting.** When it occurs to a nervous passenger, you are unlikely to see them again. Even when it occurs to a student pilot, they are unlikely to be able to handle the glider for the remainder of that flight. 'Coriolis effect'? Isn't that meteorology? Yes of course it is, but the work of Gaspard-Gustave Coriolis, published in 1835, is central to both meteorology and orientation. Despite being leaders in the development of flight, the French seem to have caused a lot of the problems! It is possible to reduce the coriolis effect by turning your eyes onto an object and then moving the head to the appropriate position. Ballerinas and ice-skaters rotating 'on their tips' move their heads in jerks, rather than smoothly with their bodies to reduce the effect. Try it – but on the ground and not just when you are about to fly.

Look these lethal traps up in Wikipedia http://en.wikipedia.org/wiki/Sensory_illusions_in_aviation Bear in mind also that the semi-circular canals cannot detect angular acceleration below about two degrees per second per second. **Thus after thirty seconds in cloud, a glider may be rolling at up to sixty degrees a second WITH THE PILOT TOTALLY UNAWARE OF THIS**. When leaving the bottom of a cloud this will be a surprise to say the least.

Instrument Flying

Instrument flying involves providing **at least a rate of turn indicator** (amongst other instruments such as an artificial horizon and VSI in addition to the ASI, compass and altimeter usually fitted). These allow the pilot to get a visual input from the instrument panel adequate to replace the natural horizon and movement around it and thus to orientate himself. Rate of Turn indicators and Artificial Horizons are controlled by gyroscopes which retain their orientation in space whatever the position of the instrument panel and thus the instrument in which they are mounted. Their use requires specific training and experience, and their ***accurate*** use requires currency. **They are a great aid to safe flying, but should not be used by untrained pilots.** In some countries gliders in competition must not be fitted with them to discourage flying in cloud in the presence of other gliders. During a World Championships held in New Zealand, a foreign competitor tried a 'short cut' through cloud to move to a different standing wave front. He lost orientation, exceeded VNE, and the glider broke up. He was able to parachute to safety.

Instrument flying is covered in depth in the Advanced Syllabus.

5) ALTITUDE and its effects

The Atmosphere

The air around us consists of roughly 80% nitrogen and 20% oxygen, this being constant at all altitudes of interest to glider pilots. Nitrogen is not of great interest to us except for causing 'The Bends' (or DCS – decompression sickness' - which will be discussed later in the chapter). Oxygen is of course vital to all life as combined with nutrition within all living cells it releases the energy that all organisms need to live. We will return to oxygen later as well.

Altitude and pressure effects

At sea level, the atmosphere exerts a pressure variously measured as about 14.7 lbs/square inch (engineers), 1013.25 hectopascals (meteorologists) or 760 millimetres of mercury (aviation medicine, mercury being identified by its atomic symbol, Hg). It varies from day to day, but not enough to be of medical importance. For simplicity, from now on 'millimetres of mercury' pressure will be referred to as 'units'.

As we ascend, the pressure drops in an exponential fashion, **to about half (380 mm Hg or 380 units) at 18,000' and a quarter (190 units) at 34,000'. If the temperature were to remain constant (it drops, of course), the volume of a given parcel of air would double (Boyle's Law – remember that?) at 18'000'. As we ascend, so the temperature drops steadily by about 2 degrees celsius per thousand feet (on average – more in clear air, less in cloud) to about minus 10 degrees at 10,000', about minus 30 degrees at 20,000' but remains remarkably constant at minus 57 degrees once in the stratosphere above 30,000'** (over New Zealand – lower at the poles, higher over the equator). Subtle changes in the rate of temperature decrease (Environmental Lapse Rate) are of course one of the foundations of meteorology. The New Zealand glider height records are well into the stratosphere (Absolute height 37,288' D Yarrell, 9 Mar 1968: gain of height 34,666' Roger Read and Peter Coveney, Nov 1st 1987) so these extreme conditions are relevant to gliding.

Trapped gas

There is free gas found in a number of places in the body, and as the ambient pressure drops, so this gas will expand although in this case the temperature remains constant at 37 degrees, and the expansion is therefore greater than that of a parcel of free air whose temperature drops with expansion as it rises. This air is found in the middle ears, the nasal sinuses, the gut, the lungs and possibly under dental fillings. Very rarely it is found elsewhere, such as within the eye after surgery, but such people should have been absolutely banned from flying by their doctor**. Remember that as the rate of pressure drop for a constant height gain is greatest at sea level, the effects that this expansion causes are greatest just after take-off and on the tow, and the recompression greatest**

in the circuit and on approach. A 'standard' launch to 2,000' is more than enough to cause problems.

The Middle Ear: Appendix 6 shows the anatomy of the ear. **Note that the healthy eardrum does not allow air to pass, but the Eustachian tube does, via its connection to the back of the throat. This tube is however normally collapsed and only opened by swallowing (hence the lollies given out in the past on airliners at the top of descent) or by the Valsalva manoeuvre (Try it – pinch the nose, close the mouth, raise the head slightly, and apply a bit of pressure by trying to blow out. You should feel the ears 'pop'). All is fine until flying with even a minor upper respiratory tract infection (or rarely hay fever).** Minor swelling effectively blocks the Eustachian tube but in fact the air normally forces its way out on the climb once a pressure differential builds up. **Not so on the descent, as the increasing pressure in the throat actually compresses the opening. The pain of a stretching eardrum due to this differential pressure can be intense. If it ruptures, it will be a problem for weeks and sometimes does not heal at all. Your landing ability is likely to be severely compromised by the pain at best, so <u>never fly if you cannot clear your ears easily</u>.**

The Nasal Sinuses: For reasons known only to evolution, we have a number of cavities within the bony structure of the face which connect to the nasal air passages via small holes. They are lined with a layer of cells that swell if infected (or allergic to pollen), possibly also producing fluid. This swelling blocks the tiny entrances and a pressure differential will occur in the climb, hopefully abolished in the descent. Ask anyone who suffers from sinusitis if it painful, but stand back in case they hit you; it is very painful. Do not fly with an upper respiratory tract infection ('a cold') or severe hay fever for this reason as well.

The Gut: The stomach and both large and small bowel contain quite a lot of air. Luckily this vents easily to the atmosphere on the climb and does not need to re-enter on the descent, so rarely causes problems. Should you be lucky enough to have a decompression chamber run (see later in this chapter), gas is likely to leave both ends of your gut (and everyone else's....).

Dental Fillings: Surprisingly often there is a minute amount of air trapped under a dental filling, or even in a diseased tooth. The sensitivity of the dental pulp is such that quite severe pain can result and although it will decrease on descent, it will remain for a time after landing. On landing carefully identify the tooth (it should be tender to touch) as your dentist may have trouble doing that later on. It is unwise to fly again until the filling is replaced.

Lungs: The lungs of course contain air, but the system is open to the outside air and, except in some disease states, does not normally contain trapped air. Healthy lungs at normal ascent rates do not normally experience problems directly as a result of gas expansion – however the process of hypoxia is discussed below.

Respiratory system

<u>Anatomy:</u> The respiratory system consists of the two lungs and the airway (the mouth and nose leading to a single trachea or windpipe which divides into a bronchus for each lung). The airway is purely a passive connection between lung tissue and the atmosphere and has a volume of about 250 millilitres. An average breath at rest inhales about five hundred millilitres of air into the lungs. Of this, half was already in the airway, exhaled with the last breath, and half is fresh atmospheric air. These mix within the lung tissue. **The air is modified as it is inhaled; dust is filtered, it is warmed to body temperature (37 degrees) and becomes fully saturated with water vapour. All of these changes are enhanced by (correctly) breathing in through the nose. The exhaled gas that was already in the airway furthermore contains about 4% carbon dioxide from the person's metabolism. The water vapour content is not expressed as a percentage as it exerts a constant pressure (of 47 units or mm Hg) at all altitudes because it depends solely on temperature. This of course means that at 18,000', with the pressure halved, the percentage of water vapour in the air in the lungs has doubled from 6 to 12%, and has quadrupled to 24% by 34,000'.**

Effect of height: The percentage of oxygen in the atmosphere is about 20% at all altitudes, but the above factors (water vapour, residual carbon dioxide and warming {= expansion}) all conspire to reduce the absolute amount of oxygen within a given volume. Thus while atmospheric oxygen at sea level exerts a partial pressure of about 150 units of pressure (760 x 20%), in the lungs at sea level its partial pressure is already down to 102 units . At 18,000', unlike the atmospheric pressure, the available oxygen in the lungs is considerably more than halved as the water vapour still exerts 47 units of pressure (now double the percentage of the total) and the other influences have worsened too.

The lung tissue: The lung is a truly remarkable organ (See appendix 7). Within each lung, each bronchus divides about thirty-two times to give a total of about 300 million tiny tubes each with an air sac (alveolus) at the tip. Likewise, each sac is beside a capillary (tiny blood vessel) and separated from it by just two thin cells. The combined surface area of the alveoli is seventy square metres (a tennis court) and the amount of blood spread over that area is seventy millilitres. Mark out seventy square metres somewhere and put 70 millilitres (a double whisky and a bit) in a glass. Imagine how thin the film is. Over this large but thin membrane, oxygen diffuses into the blood and carbon dioxide diffuses out of the blood purely because of gas pressure gradients and thus **blood leaves the lungs almost saturated with oxygen (97% plus) and almost free of carbon dioxide.**

The heart circulates the blood to the tissues, where oxygen leaves it because metabolism has used up much of the oxygen present there and created a pressure gradient drawing oxygen out of the red cells, whilst the resulting carbon dioxide diffuses into the passing blood and returns to the lungs for excretion.

It would be very simple if this was the full story, and in simple life forms it is, although they do not have lungs but use the body surface instead. In humans, and indeed all higher forms of life, haemoglobin complicates the picture although it is essential to our life.

Haemoglobin: If we relied on oxygen simply dissolved in the water present in the bloodstream, the amount carried would roughly halve at 18,000'. Indeed, some (0.3 millilitres per 100 millilitres blood at sea level) is carried this way, but that amounts to only 2% of the amount actually carried, the other 98% (20 millilitres per 100 millilitres blood) being attached to haemoglobin in the red cells. Haemoglobin is a pigment (that is it gives colour) and in the arteries leading away from the heart (where it is saturated with oxygen) it is bright red, in the veins returning to the heart (with some oxygen used up) it is 'blood red', but if at much reduced levels of oxygen haemoglobin is blue ('cyanosis'). At sea level (in a healthy lung), 97% of the possible oxygen carriage is taken up. Each molecule of haemoglobin can carry four atoms of oxygen. These respond to a very complex physiological process (in which dissolved levels of oxygen, carbon dioxide, acidity/alkalinity, temperature and other factors all play a part). In a gross simplification, the first atom to attach itself to a 'bare' molecule of haemoglobin is very firmly held and only made available in the tissues in extreme circumstances; it almost always returns from the tissues to the lungs still attached to the haemoglobin molecule. In contrast, the fourth (final) atom of oxygen is very loosely attached – it jumps aboard the haemoglobin in the lungs and willingly comes off in the tissues. These 'loose' oxygen atoms, 25% of the total, are largely what the body uses when at rest. The remaining two atoms attach and detach without too much effort. Thus, during exercise, they are the extra reserve easily available to keep our brain (and whole body) tissues fully oxygenated and functioning optimally.

If there is insufficient oxygen available in the tissues for any reason, the condition is termed *hypoxia.*

The signs (seen by an observer) and symptoms (that which is felt by the subject) of hypoxia are listed below to avoid interruption here.

Haemoglobin is a system that has evolved to work well at sea level, and indeed up to nearly 10,000' (remember that humans evolved in East Africa at a bit below this height). At around 10,000' that ('loose') final atom is no longer added to each haemoglobin molecule in the lung; the partial pressure of oxygen is insufficient for this to happen. As we ascend further, soon only two oxygen atoms are added – only half the amount is available in the tissues**. Thus the haemoglobin oxygen saturation falls to 90% at 10,000', and decreases rapidly thereafter. That may not sound much of a drop, but a sick person admitted to hospital with an oxygen saturation of 80% or less is deemed to be in respiratory failure and will be admitted to the intensive care unit and put on additional oxygen (plus possibly a ventilator). That is the situation a healthy glider pilot is in at 21,000' if he is without supplemental oxygen. Even the apparently small drop of 10% at 10,000' greatly reduces our ability to think and act appropriately to the circumstances. The reduced temperature makes the situation far more perilous as the effects of hypoxia and hypothermia are additive.**

When the lift is strong, the urge to climb to the maximum altitude possible is difficult to resist. Indeed, height equates to duration and distance attainable, so is a valuable asset for safe flying. However, even if airspace limitations allow it,

TO FLY ABOVE 10,000' AMSL, A GLIDER MUST HAVE PROVISION FOR OXYGEN FOR EACH OCCUPANT. IF ABOVE 13,000' AT ALL, OR IF ABOVE 10,000' FOR OVER 30 MINUTES, SUPPLIMENTAL OXYGEN MUST BE USED.

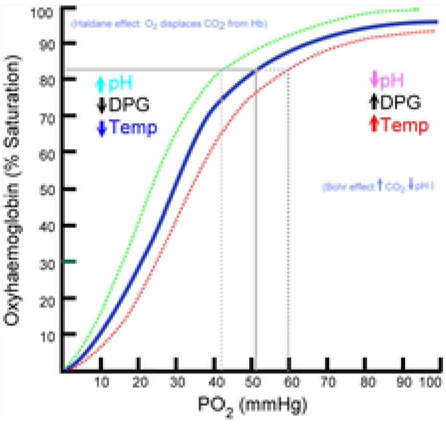
That is Aviation Law, and every glider pilot must be aware of it. The reason for the thirty minute reprieve is that tissue oxygen levels do not drop as fast as do arterial oxygen levels, due to a reserve system (myoglobin, similar to haemoglobin and present in cells). But surely a little higher is OK if you happen to get an unexpectedly good climb and do not have oxygen on board, or if you are after a long duration flight and wish to conserve supplies? After all, atmospheric pressure decreases exponentially, to about half at 18,000' and a quarter at 35,000', and people climb Everest without oxygen these days. **Surely the bureaucrats have just taken a very round number out of the hat and**

made it into a law fit to ignore – you should just use your own judgement and use oxygen when you feel the need for it.

That is a fatal misconception;

10,000' has been chosen for very specific reason, and whilst it is an easy figure to remember, it is perhaps a pity that it seems arbitrary. It is not arbitrary but the result of much scientific research and experience.

The graph below illustrates the relationship of the amount of oxygen carried in the blood at different atmospheric pressures. Read it from right to left; 100 mm Hg approximates to sea level, 70 mm Hg to 15,000'. Note how the drop is accelerating as you move left, but if this makes no sense to you, do not worry. It is not essential to understand this graph.



Haemoglobin saturation curve.

Of course **the falling oxygen level reduces your brain capacity in parallel with your physical strength.** Now is not the time to start re-assessing the rules. It is time to obey them, to the letter (and minute). So I repeat; **Supplemental oxygen must be available to all crew above 10,000' and must be used if above 13,000' if above 10,000' for thirty minutes or more.** In fact, **t**he effects of hypoxia start below 10 000' and first affect vision, the eye and brain having a high oxygen requirement. **Colour vision and visual acuity start to fail around 6000' and this is a major reason why newer aircraft types have a cabin altitude lower than the usual 8,000'** (Airbus A380 5,000', Boeing 787 Dreamliner 6,000'). As to climbing Everest without oxygen, as mountaineers ascend they acclimatise; this is a complex physiological response that takes days to occur and so is not relevant to pilots who climb and descend within hours, not days.

The symptoms of hypoxia

The symptoms of hypoxia vary between individuals, **and <u>are lethally insidious.</u>**

They include **Euphoria**

Personality changes

Decrease in colour perception

Task fixation (e.g. checking and rechecking altitude – without realising why)
Loss of judgement and self criticism
Decrease in peripheral vision
Dimming of vision
Clumsiness, fine tremor
Slurred speech
Forgetfulness
Increasing sensitivity to cold

And as it becomes severe

Cyanosis (blue colouration, probably not noticed due to reduced colour vision and confusion)
Confusion
Slowed movement, hypoxic flap

Finally

Unconsciousness and death

Note however, that together with these symptoms, there are likely to be some of the symptoms of hyperventilation (see below).

Time of useful consciousness

If the oxygen system fails, or is not used at all when required, unconsciousness is not immediate due to the reserves of oxygen in the tissues. It is thus related to altitude. For a while you will be able to think and act fairly rationally and thus be able to sort out the problem either by losing altitude or by solving a problem with your oxygen equipment. After a while, however, even although you are still conscious, the brain is so befuddled that death is inevitable unless some lucky chance (hitting bad sink, perhaps) saves you. Your 'Time of Useful Consciousness' is up. Those who have done a chamber run and experienced hypoxia or even gone unconscious (an extreme rarely reached) know that it is not a bad way to die – until 'rescued' by their colleagues replacing their mask, all are unaware of a problem and many deny they were ever unconscious. The idea, however, is not to die at all. **Appendix 8 gives a range of times of useful consciousness at various altitudes, varying from 10 - 15 minutes when sitting at 18,000' to nine seconds if exercising vigorously at 43,000'. These figures are very approximate, and were compiled with subjects in a chamber at fairly normal temperatures. If hypothermic (and glider pilots have no cockpit heating and ascend slowly enough to become 'cold soaked' over time) the times are shorter. Even then, there is the supposition that you are aware when the emergency starts. You probably will not be aware if a bottle empties or a leak develops. Study your oxygen system and its manual until you can trouble-shoot in your sleep: You may have to one day. It is helpful (but not necessarily a guarantee) to regularly check your oxygen set when in use. The manual will be more specific, but in general check contents, tubing, and the cannula or mask.**

Oxygen systems: Glider pilots regularly use personal oxygen systems and as such are different to pilots flying light powered aircraft who rarely venture above 10,000' and then only in the few pressurised light aircraft types. Oxygen systems for gliders may use nasal cannulae (small tubes inserted into each nostril) or masks (fitting tightly over both mouth and nose). The full system has a reservoir (pressurised bottle), a regulator to provide a steady supply as a usable pressure, necessary tubing and taps as well as either a mask or nasal cannulae. Well-fitting masks are more efficient, nasal cannulae are more comfortable. **As a rough guide, nasal cannulae can maintain full arterial oxygen saturation only to about 18,000'; above that a mask is required.** A perfectly fitting mask and 100% supplemental oxygen maintains sea level arterial oxygen pressures up to 34,000' (40,000' is attainable with an arterial oxygen level equivalent breathing air at an altitude of 10,000', the recognised safe limit).

Above this altitude cabin pressurisation or pressure breathing (used in some military aircraft) is the only way to get adequate oxygenation, so spare a thought for the Spitfire pilot who attained 43,000' (in an unpressured Spitfire Mk V) in 1943 in order to attack a (pressurised) Junkers Ju 86P reconnaissance aircraft over south-east England. This remains the highest ever air combat. **The bottles must be filled with 'dry aviation oxygen' as industrial oxygen sources may contain water vapour (which will form ice and block valves) or even poisonous impurities. It is imperative that you are totally familiar with your system and able to use it and to check connections etc in your sleep; you may have to, in effect. It is a foolish economy to buy a second hand system unless the information manual is available. Just hoping that switching it on will work is not sufficient.** The fact that aviation oxygen has to be entirely free of water vapour means that more water is added within the nose and lungs to saturate that dry gas, leading to an extra loss of 200 mls of water an hour in the exhaled gas. This adds to the fluid intake required to keep hydrated.

<u>The oxygen paradox:</u> Beware of the oxygen paradox. This is a phenomenon poorly understood by even experts, but not uncommon. **If you are already hypoxic when supplemental oxygen is started, your hypoxic symptoms may temporarily worsen and you may feel very unwell, as if being poisoned.** This feeling goes after just a few breaths but has led to people removing their mask again and thus worsening their hypoxia. The reason is poorly understood, but it seems that when supplemental oxygen is started and the arterial oxygen level suddenly rises, the arterial walls constrict and thus temporarily worsen the situation. Just as you must believe your gyro instruments when you need them, you must believe in your oxygen system even though at first it seems contaminated; the sensation will cease after just a few breathes. **If you do suffer from the oxygen paradox, you were significantly hypoxic before you selected supplemental oxygen. Learn that lesson well and do not get into that situation again.**

Smoking: Smokers inhale small but very significant amounts of carbon monoxide. Carbon monoxide binds to the oxygen-carrying haemoglobin with approximately two-hundred times the affinity of oxygen. Thus tiny concentrations of carbon monoxide displace a lot of oxygen from the arterial blood, and take many hours to diffuse out again – General Practitioners demonstrate this to smokers using a carbon monoxide monitor as a 'lie detector', proving to people that they have smoked in the last few days despite their protestations to the contrary. **If you have smoked in the days before flying high, you will become hypoxic sooner;** it is as simple as that.

Chamber training: Hypobaric chambers are available in some centres (to our benefit, RNZAF Auckland has the only hypobaric chamber in the southern hemisphere accessible by civilians) and allow pilots to experience hypoxia under controlled conditions. A chamber run may seem expensive ($200 – 300), but a visit by a Club group is a very good idea.

In the old days, as the pressure within the chamber dropped, at **around 6,000' the colour seemed to fade from a gaudily painted picture.** Masks went on at that point. The run included rapid decompression (8 – 25,000' in five seconds). It suddenly became very cold and 'cloud' formed around you. A bit of meteorology revision! Once settled at that pressure, each individual in turn **removed his mask** as the others watched. The mask was left off, the instructor giving the person a four-figure number to remember when he judged the person was 'about to go', asking for it to be read back. **The person soon collapsed,** having his mask immediately refitted for him. Recovery was almost immediate, but the subject often denied he had collapsed, and denied being given a number to remember. Some heated arguments ensued! In turn, each experienced this, possibly **only believing they had actually become unconscious once they had seen their friends equally sceptical despite collapsing**. Some would have experienced **the oxygen paradox,** and forcibly if weakly resisted having their mask refitted. Another exercise was to draw three shapes across a page – say a triangle, a circle and a square. The instructor told you to do an identical line of these shapes every so often after your mask was removed until you were about to lose consciousness, repeating the instruction as you recovered after your mask was refitted. The result was a graphic record of your descent into (and recovery from) hypoxia as your neat drawings descended into chaos and then recovered. It made a nice souvenir of the day as a reminder of the **dangers of hypoxia.**

Nowadays, initially subjects breathe 100% oxygen (which seems no different to air) for thirty minutes. This will raise saturation within the arterial blood to 100% very quickly; the reason for a prolonged thirty minute 'pre-breathe' is to negate the very small risk of DCS (decompression sickness - see below) by flushing out via the lungs some of the nitrogen in solution in tissue fluids. Masks are worn from the outset, and the rapid decompression is from 5,000' foot to 16,500' cabin altitude in ten seconds. One at a time (so that the others can see, and the instructors monitor that person very closely) each removes their mask to experience hypoxia. They are likely to experience rapid breathing, reduction of colour vision and the uncertainty of initial confusion. As soon as they start to feel symptoms, they replace the mask themselves, the instructor doing that if needed. **A further benefit of a chamber run is that some people have hypoxic sensations that, whilst being variable, are constant to that individual.** Some 'smell' strange smells, some 'see' strange things, and so on. **If you do get an unusual sensation, be very aware if it returns whilst you are flying. Descend immediately and check your oxygen supply.** YouTube has several videos illustrating hypoxia with and without rapid decompression. Have a look at some of them via this link:

http://www.youtube.com/watch?v=m8ooGY8Jbqw

Hyperventilation

Hyperventilation is not confined to flying, but is **quite common in the flying environment especially in those who are inexperienced.** Normally our breathing (and most certainly our heart rate) is controlled subconsciously. However, breathing can become a voluntary activity if we wish, and indeed those with great self-control can hold their breath until they become unconscious, at which time breathing returns to normal. When we exercise, the muscles require more oxygen to produce energy from nutrients, and produce more carbon dioxide as a result. Receptors in the cardio-

vascular system and brain speed up both the heart and breathing rates as required to transport this increased load. This control mechanism is more geared to carbon dioxide levels than oxygen levels, keeping the pH (acidity/alkalinity) of body fluids remarkably constant.
Such is the normal physiological response, appropriate to the demand. However**, sometimes people breathe too fast for their physiological needs. This is called hyperventilation, and it is very unpleasant for the subject. By breathing too fast for the body's needs (the heart also speeds up), no extra oxygen is transported by the blood; the saturation at rest is 97% or better, and there can be no useful increase in that. What does happen with inappropriately fast breathing is that the carbon dioxide level in the blood and tissues falls, making the body fluids too alkaline.** Remember that when breathing at rest, only half of the gas in the lungs is vented to the atmosphere; the other half remains in the airway and becomes the first half of the next breath in, the two parcels of air mixing in the lungs. Thus half of the gaseous carbon dioxide in the lungs is excreted with each breath. If the breathing rate rises, so the amount of carbon dioxide excreted rises and yet no more is being produced in the tissues. The amount of carbon dioxide in the blood falls, the body fluids therefore become more alkaline and the person feels very unwell. **Symptoms vary greatly, but include:**
Severe apprehension or panic
A very rapid pulse or palpitations (irregularity of pulse)
Light headedness, dizziness, fainting
Chest tightness or even pain
Numbness or tingling around the mouth and hands or feet
Spasm of the forearm and hands
Nausea, abdominal discomfort

Likely causes in vulnerable passengers (it rarely occurs in pilots and almost never in handling pilots) have a common theme, fright. They include severe turbulence, aerobatics, sudden noise (airbrakes deployed), hypoxia, excess solar heat or just being unfamiliar with gliders or small aircraft. The vulnerable person certainly felt apprehensive before starting to hyperventilate, and now his fears are 'confirmed' – he is convinced he is having a heart attack, a stroke, or just simply dying.

This unfortunate situation should be avoided by a thorough pre-flight brief and restrained, gentle flying with inexperienced passengers.

If nevertheless hyperventilation occurs, the situation is serious, as the sufferer may become unconscious (when recovery is rapid), interfere with the controls, open the canopy, or whatever. Immediately recover to gentle flight and proceed to terminate the flight as soon as possible with the gentlest manoeuvring. If it is possible to reason with the sufferer, ask them to slow (but not stop) their breathing and to take shallow breaths. Reassure them profusely and talk them through the remainder of the flight ("We are going to turn left now", "Keep looking at the far horizon", "You will hear the airbrakes come out now"). Try to get them to re-breathe exhaled air by putting a sick bag over their mouth (this decreases the loss of carbon dioxide by increasing the volume of 'the airway', and may be needed for its primary use very soon anyway!) or by using a rolled up map as a tube to breathe through. If there is the slightest chance of hypoxia (8 000' or above) and

oxygen is available, then use it; it could have a psychological benefit even at low altitudes especially if they think they are having a heart attack.

Once back on the ground, do not rush them out of the glider. Sit there gently. Sympathy now might encourage them to glide again, but probably not for a while.

Decompression Sickness (DCS) and flying after diving.

Everyone has heard of 'The Bends' (a form of DCS), but normally associate the condition with scuba divers coming to the surface too fast. **It can however affect glider pilots, especially if they have done a scuba dive in the preceding day or two.** Nitrogen dissolves throughout the body just as do oxygen and carbon dioxide. In the tissues, its partial pressure matches that of the atmosphere, so there is no net movement of nitrogen in or out, provided we stay at sea level. If however, the environmental pressure rises, as when scuba diving to 10 metres (which doubles the pressure on our bodies to two atmospheres) the amount of nitrogen in the body (slowly) doubles. A sudden ascent to the surface from this depth is unlikely to cause trouble, as the doubled amount of nitrogen exposed to sea level air pressure can remain in solution. Not so, however, if a person dives deeper and stays there for long enough to allow more nitrogen to dissolve in the tissues. A rapid ascent from say thirty meters (four atmospheres pressure) will cause the gross excess of nitrogen to come out of solution and form bubbles, particularly in places where the blood supply is relatively poor and thus transport of the excess nitrogen to the lungs in the bloodstream takes longer. Except in extreme cases, bubbles do not form in the blood.

The actual site of the bubbles determines the symptoms and classification, as the effect is caused by presence of the bubble which is expanding as the pressure drops. Bubbles in the joints cause joint pain and stiffness, hence 'The Bends'. If the brain is affected, it is 'The Staggers', if bubbles do reach the lungs 'The Chokes'. These colloquial names date back well over a century.

Glider pilots reaching 18,000' are subject to a pressure reduction of one half of an atmosphere, which is high enough to get decompression sickness especially if ascending rapidly in a good wave. Above that height the problem steadily increases in frequency, especially if above 25,000' for prolonged periods. The risk of decompression sickness with altitude is greatly increased if the pilot has been scuba diving in the previous twenty-four hours as he will have taken off still with some excess nitrogen in his body tissues. In that instance, the decompression sickness may occur at much lower altitudes. Be aware of the possibility and descend if it happens (joint pains, difficulty and pain breathing, skin sensations, localised muscle weakness etc). You are unlikely to have any serious or permanent effects **unless you continue to ascend**.

6) CARDIOVASCULAR SYSTEM

The Cardiovascular system The cardiovascular system consists of the heart, the arteries and the veins, and comprises the transport system of the body. It has many transport functions, but we are concerned primarily with transport of oxygen to all tissues, especially the brain, and carbon dioxide back to the lungs.

The heart (which is a simple pump and works by contraction of its muscular walls, the direction of flow being controlled by valves) actually drives two circulations. The circulation we normally associate with the heart is of oxygenated blood pumped through the arteries to the tissues, where it gives up some of its oxygen and picks up carbon dioxide before returning to the heart via the veins. This is achieved by the left side of the heart, whilst the right side of the heart, working at lower pressures, pumps blood to the lungs to lose carbon dioxide and gain oxygen before returning to the left side of the heart to start the cycle again.

Blood pressure and 'g'. Blood pressure is usually measured in a person's forearm, as this is more or less level with the heart whether we are sitting or lying down. The typical figure is 120/80, this being the highest pressure reached at the end of contraction of the heart muscle and the lowest pressure reached during the heart muscle's relaxation. The cycle is repeated about seventy times a minute as rest, this being the heart rate. As with oxygen pressure measurements, the units of blood pressure are millimetres of mercury (mm Hg) but that is unimportant. The figure of 120/80, whilst widely quoted, is no more definite than is for example, the average height of adults (in New Zealand, 177 cm for males, 165 cm for females). It is merely an average figure in healthy people and your normal blood pressure may be a bit higher or lower. When we are sitting, for example in our glider, the blood pressure is less in the brain than in the heart as the brain is some thirty centimetres above the heart. Converting that to millimetres of mercury, a typical figure in the brain would be around 90/50.

'g' So far we have only talked about the 1 'g' (or normal) situation, but you will be familiar with the expression of *pulling 'g'* when doing aerobatics. 1 'g' is the force we are subject to at rest on the surface of the planet, where our weight equals our mass. However, if we were to stand on the moon, where the force of gravity is just one sixth of that on Earth, we would weigh just one sixth of the Earth figure, say 15 kg instead of 90 kg; our mass has not changed, but our weight has. In flying the opposite often occurs. If we turn steeply, our weight increases. In a steady sixty degree banked turn, for example, we are subjected to 2 'g' or twice the force of gravity and therefore our weight is doubled. A smoothly executed loop takes us to 3 'g', or to 4 'g' if a little ham-fisted on the pull out.

If we are experiencing 2 'g', the pressure drop from heart to brain is doubled and if there were not compensatory mechanisms in the body, the blood pressure in the arteries of the brain would be only 60/20 and at 4 'g' (that ham fisted loop!) it would be zero. No blood pressure means no blood flow, so no oxygen would reach the brain and we would soon be unconscious. Tall pilots suffer more from 'g' forces simply because their brain is further above their heart. Fatigue, dehydration, hypoxia and a naturally low blood pressure also reduce 'g' tolerance.

In fact humans can take about 5 'g' (or 6 'g' briefly), which is about the safe limit for the glider's structure anyway. This is achieved by the "Anti 'g' Straining Manoeuvre" (AGSM) which is really just a big name for a subconscious reaction, that is tensing the muscles of the belly and legs to resist the downward force, whilst still breathing hard thereby forcing blood back to the heart rather than letting it pool in the lower body. Glider pilots are further helped as most glider seats recline steeply. Whilst this is to reduce the fuselage cross section and thus drag, it also lowers the head a little which helps us to tolerate increased 'g'. The pilot's seat in an F-16 reclines at 35

degrees as the aircraft can pull very high 'g' and this reclining is reckoned to increase his 'g' tolerance by 1'g'. Military pilots also use a 'g' suit to prevent blood pooling in the lower body, but this is not dramatically effective. It adds only about an extra 1.5 'g' tolerance and with much weight training to strengthen the muscles, plus the AGSM and a reclining ejector seat, a trained military pilot can tolerate a sustained force of 8 'g' and remain conscious.
You will experience small transient increases in 'g' during your training. A competition pilot, spending much time in a sixty degree banked turn to exploit narrow thermals experiences 2 'g' for long periods. That is very tiring indeed.
As 'g' forces increase, you will notice a progression of effects:
a) 'Tunnel vision': Peripheral vision is progressively lost. Blood enters the eye by the optic nerve and as the arteries branch out they get smaller and the pressure within lower. The blood supply ceases first at the periphery, the effect moving inwards as 'g' increases.
b) 'Grey out': Colour vision is lost. Remember that the cones in the retina (see 'Vision' above') are very sensitive to hypoxia.
c) Blurring of vision.
d) 'Black out': This is when all vision is lost BUT THE PERSON IS STILL CONSCIOUS. This is not the same meaning as a 'black out' as in fainting.
e) 'g' LOC: ('g' induced loss of consciousness) When a person exceeds their personal limit, about 6 'g' (but possibly as low as 4 'g' – a loop) they will become unconscious. This can be very damaging to the neck. A human head weighs about 7.5 kilograms, and thus at 6 'g' weighs 90 kg. For this reason, when beginning aerobatics under instruction be very careful about turning your head; try to stick to gentle fore and aft movement, moving just the eyes rather than turning the head, until you know what to expect. Normally, if a solo pilot does experience g-LOC, the 'g' force will reduce as they relax on the controls and they will recover quickly without injury unless the glider crashes in the meantime.

Reduced 'g' **Glider pilots also experience reduced (rarely even negative) 'g'. If the stick is eased forward a little (as in a stall recovery) but then held there, the centrifugal force will reduce a person's weight towards zero. At zero (a gentle bunt) the sensation is similar to that of falling through space, and some people find this extremely disconcerting. There have been instances where a glider has crashed, probably due to stall recovery being taught and the student panicking and pushing the stick hard forward such that the instructor cannot recover from the steepening dive, the glider exceeding VNE and breaking up. To avoid an inexperienced student coming across this sensation unexpectedly and reacting dangerously, before completing the 'A' certificate syllabus a student experiences reduced 'g' in a briefed dual exercise. As with most unpleasant experiences, expecting it removes most of the unpleasantness.**
Humans generally react to negative 'g' badly, and even minus 2 'g' is very unpleasant. Apart from a feeling that your head is about to explode, vision 'reds out' as the retinal blood vessels engorge. Because pilots cannot take significant negative 'g', so aircraft structures are generally only designed to take about half the negative 'g' compared to their positive 'g' limits.

Aerobatic pilots Few glider pilots become qualified aerobatic pilots even but their efforts are greatly appreciated by airshow audiences. They find what their capabilities are by progressive training but need to be aware that 'g' tolerance (not to mention motion sickness tolerance) is acquired slowly but lost rapidly, and thus they must retrain after a layoff of only a few weeks.

7) THE EARS

Hearing Whilst effective pressure equalisation within the middle ear and correct functioning of the vestibular system (see above) are essential in gliding**, good hearing itself is not vital.** Learning to glide is very difficult (but not impossible) for the deaf as instruction is so much harder to give. On the ground, instruction can be given by signing or written methods, but once in the air, the instructor has to act mostly as a safety pilot whilst the deaf student learns by his or her errors. A trained glider pilot can continue to fly after the onset of deafness provided that use of a radio is not essential. There are a (reducing) number of sites where gliders still operate 'nordo' (no radio) in this country. The deaf pilot is also robbed of the sound of passing air that is so helpful when learning to glide, but there are enough other ways to assess the approach of the stall to allow safe flying when deaf.

8) THE GLIDING ENVIRONMENT

Environmental temperature stress Glider pilots are subjected to far more climatic stress than their power colleagues. Without lift there can be no (sustained) gliding, and most lift requires sunny weather. **Before take-off the cockpit can feel like a furnace once the canopy is closed. Being airborne brings the welcome relief of the air vent, but a successful climb especially in wave lift brings rapid cooling and no glider has any form of internal heating nor is the pilot normally doing much physical work to keep himself warm. As the air temperature drops at about 2 degrees C for every thousand feet gained, at 10,000' it will have dropped by 20 degrees and be around zero, and by 20,000' well below zero. The glider pilot cannot easily add extra layers of clothing as he climbs, so must plan ahead and launch overdressed. If, however, he is not successful and spends time at low altitudes scratching around for some lift, he will be very over dressed and far too hot. Finally he may have to land out, and needs warm enough clothing to survive (and hopefully be comfortable) in the cool evening – or even night – before his retrieve crew arrives.**

Cold weather clothing technology has made enormous advances, driven by mountaineering since Sir Edmund Hillary stood atop Mt Everest sixty plus years ago wearing the then new 'Ventile' fabric. Just what you should wear when a high (and thus cold) flight beckons is best discovered by talking to experienced glider pilots and experimenting yourself as you progress; it is not really a problem while you are learning to glide**. However, from the very start, a suitable hat (light in colour, well ventilated, with a brim that does not obscure the visual field), good wrap-around sunglasses and sunscreen on all exposed skin (wear long trousers if possible, cotton being the best fabric) are essential.**

If one is underdressed, hypothermia may insidiously develop, if over-dressed for the conditions, then heat stress (or very rarely heatstroke) will follow. Hypothermia is largely the enemy of experienced pilots who have learnt to exploit lift well. **Heat stress, by contrast, can affect us all even on a fairly routine day of club flying.**

Hypothermia As the body cools, for as long as possible the core temperature (the temperature deep in the body, and most importantly, in the brain) will be maintained close to 37 degrees Celsius for as long as possible. The blood vessels in the skin contract to minimise heat loss, and the muscles shiver (to increase heat production). When this is no longer effective, then the core temperature starts to drop. **The progression is aptly described as "grumble, mumble, stumble, crumble". At around 33 degrees Celsius shivering stops but by then brain function is far below normal and the person is beyond being able to help themselves. Only outside help or sheer luck will save them. Incipient hypothermia also makes a person more susceptible to hypoxia, which is very likely to be present at the same time. In a two-seater, the individuals may well not become hypothermic at the same time, depending on clothing, individual fitness etc., so each needs to be aware of the other's state. A sense of humour failure ("grumble") is a vital sign.**

Assuming a happy outcome, recovery from hypothermia is a slow process. **It takes hours for the body temperature to rise to normal even in a warm bath (which itself will cool surprisingly rapidly with a cold person in it) and even then cerebral ('brain') function will lag hours behind. A person honest enough to admit he became hypothermic will be well advised to take the next day off gliding as well as the day in question.**

Hypothermia is also a problem after landing out. The fatigue of a long flight exacerbates the problem. There should always be light but warm clothing available in the glider, remembering that a lot of the heat lost is via the head (so have a balaclava or similar) and that heat loss is greatly increased if clothes are wet (because of sweat or rain – so have a light waterproof on board). Cold hands may need light gloves. Suitable food is essential.

<u>Heat Stress</u> Hypothermia is perhaps the province largely of those few who fly very high, but to be too hot is not uncommon in New Zealand**. HEAT STRESS IS A VERY IMPORTANT PROBLEM IN GLIDING**. Normally sweating and sensible clothing keeps our temperature only very slightly above the norm. **The importance of remaining well hydrated at all times whilst gliding cannot be over-emphasised** as even without seeming 'sweaty' a person might be losing a lot of fluid on a hot day. As the body temperature begins to rise, more **symptoms occur in random order. These include headache, muscle cramps, nausea, a rash, dry eyes and mouth, reduced concentration, physical weakness and so on. These signs may not be as obvious to the sufferer as you may expect and, very rarely, the situation may proceed to heat stroke. IF IN ANY DOUBT ABOUT HEAT STRESS BEING PRESENT ("if there is any doubt, there is no doubt") then it is time to terminate the flight as soon as practicable; not an immediate land out in an unfavourable spot, but a safe landing soon is the best procedure.**

<u>Heat Stroke</u> Heat stroke is a medical emergency very unlikely to be encountered in gliding, which is just as well as over half of those affected die. During even common illnesses, the normal body temperature may rise to 40 or 41 degrees Celsius with no lasting effects. However, a core temperature of 42 degrees Celsius may be fatal, a terrifyingly small margin of safety. As a person approaches this figure, **effects on the brain predominate: slurred speech; confusion; disorientation; hallucinations and collapse. Sweating ceases, the skin feeling dry and rather like warm plastic to an observer. Once sweating ceases, further temperature rise is rapid, leading to collapse, convulsions and death.**

Treatment in the early stages of heat stress involves the obvious; get to a cooler environment (if one is caught scratching for lift at low altitude whilst dressed for high altitude, then consider terminating the flight and landing whilst you are still in reasonable physical shape) and get/remain well hydrated. Once back on the ground, get in the shade, dressed appropriately. This all comprises good airmanship.

Treatment of heat stroke is really beyond the scope of this text, but it is an emergency requiring a 111 response if possible. Get the victim into the shade, remove most of the clothing, apply tepid sponge, fan them if possible (use the tow plane?) and be ready to deal with a convulsion and to carry out basic life support (airway, breathing, circulation) whilst awaiting help.

9) FITNESS TO FLY, and especially to act as Pilot-in-Command

AM I SAFE?

The NZCAA strenuously (and correctly) promotes the **"IMSAFE"** acronym for all aircrew, not just pilots. This is a check list to run through before deciding to fly to confirm that you are indeed **fit to fly not only at that moment but for the anticipated duration of the flight.**

There is, however, an objection to this acronym; by sounding like a statement, it leads the brain to automatically endorse the supposition that you are indeed safe to fly rather than asking an open question. By using the acronym AM I SAFE?, not only is an open question asked and (hopefully) a more objective answer obtained, but an extra 'A' is included, allowing *ATTITUDE* to be included. The other letters are the same headings as with IMSAFE although in a different order:

A **Alcohol (or drugs)**
M **Medication**
I **Illness**
S **Stress**
A **Attitude**
F **Fatigue**
E **Eating**

Alcohol (or recreational or illicit drugs)
I make no apologies for putting this first and foremost. Alcohol is a significant cause of aircraft accidents, even amongst professional pilots. Quite categorically, flying and blood alcohol content must never be allowed to mix and hence the twelve hour 'bottle to throttle' edict (perhaps 'alcohol to "all out"' for glider pilots). Even after blood alcohol has returned to normal (there is always some in our bodies from normal mammalian metabolism), **'hangover' effects can persist and are dangerous.** Whilst alcohol is present, decision making is poor, usually veering towards the reckless as one of the primary effects of alcohol is reduction of inhibition. Add to that poor co-ordination, another primary effect of alcohol, and spice the mixture with poor vestibular function (see 'Orientation' – alcohol both enters the fluid within the canals more slowly than it does the blood, and leaves later. This two-way lag leads to differing fluid concentrations that degrade balance for far longer than the duration of measurable blood alcohol). This is a lethal cocktail. Sadly alcohol-related aviation incidents will probably never cease but Gliding should set an example for other groups to follow.

Medication

Many medications taken for even minor reasons affect the senses in a way not apparent in daily life. Anti-histamines, or the residual effect of sleeping tablets are examples. Preferably only ask an aviation medicine qualified doctor about these effects, but if asking another doctor or preferably a pharmacist make sure they know you are the pilot, not just a passenger. Remember also that **it may not be the medication you are taking but rather the reason why you are taking it that is the danger.** There is no reason why a person should not take common antibiotics and fly, but the chest infection they think they have almost recovered from certainly is significant. As an example, a rostered instructor arrived at the field having taken some paracetamol and feeling his headache and lassitude were now sufficiently controlled to carry out his duties. On his fourth launch, with a passenger aboard, the airbrakes came open as speed increased on the take-off. He coped, but clearly he had not completed his pre-takeoff checks. It was not the paracetamol that was to blame, but the reasons (mild illness) for which it was taken. A relief instructor should have been called in. (NB: There is more detail on illness and medication below)

Illness:

No glider pilot should fly if unwell; especially those under real or perceived pressure to fly, be they the duty instructor, a competitor with a chance of winning on that final contest day, or someone due to display before an airshow crowd. All illnesses (and many injuries) affect those very senses or judgements which in turn affect safety in flying. **The vestibular system (see 'orientation) is particularly vulnerable to illness, and problems caused by ear, nose or throat infections may well not show themselves until descent and landing,** the most critical phase of the flight.

Stress

Stress is the non-specific response of an individual to demands for change, or an excess of demands over an individual's ability to cope with those demands. Stress has many causes, for example competitions, arrangements at a gliding camp, changes to routine eating and sleeping arrangements, challenging conditions, excess heat or cold and so on. Nevertheless, some stress is essential for good let alone optimal performance. Excessive stress carried into the cockpit leads to poor if not dangerous performance and reduces a pilot's ability to respond favourably to those stresses that are an inevitable and indeed positive aspect of each flight. There is very definitely an optimum stress level for a pilot: neither too little nor too much. Both extremes often contribute to accidents.

Attitude

Honestly ask yourself why you intend to go flying today. Is it to accept the challenge we all love, and the joy and beauty of flight, or is it to avoid something else (bad relations at home) or to prove something ("only REAL pilots would fly when it's this gusty")? Have positive reasons. Do not fly solo when at the limit of currency and in some doubt about yourself or the conditions just to renew currency. Far better to slip out of currency and later fly with an instructor on a better day than to try to renew it solo at a bad time.

Fatigue

This is more physical tiredness as opposed to the results of prolonged stress, be it simple inadequacy of sleep or too much done since the last sleep.

Either way, flying is not a good idea, nor is any active participation at the Field; **the wing-runner needs to be as alert as the pilot**. Maybe it is time to show your team spirit and keep the flying record instead if you feel tired. Fatigue can sometimes be avoided by team work; all too often, a few members seem to do all the physical work whilst others sit in the caravan and chat. Often those few always on the go are the older members, so make sure you put in your fair share of the effort required. The duty instructor deserves special consideration; he does the most tiring job of all and yet has the most decisions to make and the least opportunities to eat and rehydrate.

Eating

A day at the Field is not an inactive one. Indeed, glider pilots probably need their medicals more to ensure they can keep up with the physical demands of the day than to avoid sudden incapacitation in flight. You must eat and **above all drink adequately**, probably **better 'grazing' than** 'dining' to avoid hunger and a slump in alertness. Remember that **simple sugars such as glucose or fructose lollies can cause rebound hypoglycaemia** (in response to a sugar load, the body produces insulin to drive the sugar into cells. This can result in a blood sugar level LOWER than before the lollies were sucked, the brain suffering as glucose is the only nutrition it can make use of) and that complex carbohydrates (the muesli bar) give a gentle rise and maintenance of blood sugar levels. A banana is often recommended and muesli bars are convenient in flight. As to fluids, water is difficult to beat. Expensive sports formulations give some slight improvement in performance that might help in a contest or exceptionally long flight, but are not essential in club flying. Remember that fizzy drinks not only cause altitude related gaseous effects but contain thirst suppressants (to boost their sales) and encourage you to under hydrate. These chemicals make your thirst cease before you are fully re-hydrated, thus enhancing the 'thirst quenching' effect whilst encouraging under-hydration.

Note that of the above factors, only the last one, food and fluids, is actually remediable when at the Field. It follows that you should carry out this self-assessment before you leave home in order to be objective; once you are at the Field, the chances are that you will fly anyway rather than decide and accept that you are not fit to do so.

This honesty with your fitness to fly should spread to an assessment of your performance as you drive to the Field. Hopefully we all try to drive safely and courteously, but are we achieving that as we go to the Field today? Are we **under-aroused (startled by unexpected actions of another driver)** or **tense (lots of bad drivers on the road today....)** or just un-co-ordinated (pretty awful gear change that)? **Cognitive failures** ("action not as intended" - using the wipers to signal a turn or forgetting this is your wife's automatic as you declutch with the brake pedal) **are particularly worrying**; they lead to inappropriate actions in flight, such as raising the undercarriage whilst doing the pre-landing checks (having forgotten to raise it after casting off tow) and then landing with the undercarriage up, for example. Pulling on the rudder pedal adjustment knob rather than the yellow release knob when faced with an abnormal situation necessitating an emergency release is a particularly unforgiving possibility. The converse has happened; on a cross-country tow, a less experienced pilot pulled the yellow release knob at low altitude when intending to adjust his rudder pedals, giving his instructor some anxious moments until the latter made a successful paddock landing. Remember the mantra: **LOOK; IDENTIFY; OPERATE**

Objective self-assessment is a very difficult art, but be honest and if **you see that you are tired, tense or just having a bad day, just go and be sociable.** Do not think you will sharpen up when the pressure is on. You may not.

Illness and medication

We must look at illness, both short term (acute) and long term (chronic) and drugs of all types from 'over the counter' remedies through prescribed medicines to illegal drugs**. Alcohol and flying merits a special mention.** Smoking has important negatives effects, and even our state of hydration and nutrition is vital. It may seem that no-one is ever fit to fly; not so of course, but remember Captain Lamplugh's words over eighty years ago:

"*<u>Aviation</u>* in itself is not inherently dangerous but to an even greater degree than the sea it *<u>is terribly unforgiving of any</u>* carelessness,*<u> incapacity</u>* or neglect"

<u>Illness</u> **Even after the effects of any illness seem to have gone, and we are fit for daily life and normal work, we may well not be safe to fly for some days more. That is particularly so for any ear, nose or throat illness (ear infections, sinusitis, tonsillitis) or any lung infection (bronchitis let alone pneumonia). Generalised infections such as 'flu-like illness' or shingles, decrease performance for days if not weeks after apparent recovery. Increased susceptibility to disorientation, hypoxia or hypothermia, and poor decision making in general** may not be apparent until not only airborne, but in a difficult situation. For most glider pilots there is no pressure at all to fly. **For some, instructors in particular, there may be self-inflicted pressure to fulfil duties. It is excellent airmanship to admit you are not fit to fly, and equally excellent for others to support you and cheerfully take over your duties.**

<u>Specific medical problems:</u>
Hydration: Correct hydration is vital, and in a physically active day when it is hot, dehydration is very likely. With **dehydration comes poor mental performance.** Remember that fizzy drinks contain thirst suppressants to increase their thirst quenching (but not hydrating) effect, **so water is best.** Caffeine is also a diuretic (i.e. causes excess fluid loss) and anyone needing caffeine to glide should not be gliding. Specialist sports drinks with sodium, potassium and carbohydrates have only marginal benefit in Club flying, but might help in competitions. Try them out in non-competitive situations first.
The only true guide to proper hydration is of passing urine during the day, preferably not concentrated (not dark in colour). Granted, many launch sites lack toilets, but safety is more important that prudery. **The problem comes in the air on a long flight;** on any flight of two hours, certainly of three hours, urine should need to be passed – the bladder can barely hold five hundred millilitres. Some gliders (e.g. PW-5) have urine tubes fitted, so check and familiarise yourself with them, and ready the tube during your pre-pre flight checks. Otherwise develop a system to contain the urine, some sort of tube/bag/absorbent material/male nappies.... As a safety measure, sitting

on an incontinence pad may save a smelly cockpit afterwards. Whilst little may be written in gliding texts, there is a surprising amount of expertise available in most clubs if you ask discretely.

Upper Respiratory Tract infections: URTI include those of the sinuses, ears and throat. I make no apology for **repeating that these are an absolute bar to flying until full recovery and some recuperation time has occurred. The infection itself will reduce your mental capacity and ability to make good decisions, whilst the effects of pressure will cause pain if not damage.** Remember that as the pressure drops (on the launch) the air can usually force its way out without too much problem. However, due to the anatomy which tends to act as a one-way valve, the air cannot get back in on descent. If you think the discomfort as you descend slowly is a problem, wait until the final approach. **The greatest pressure change for height is closest to the ground, as is the descent rate on finals**. Severe pain (and possibly long term injury) happens at the most critical phase of the flight. Do not fly even, as a passenger, with respiratory infection..

Should you inadvertently find you have a problem clearing the ears, **remember the Valsalva manoeuvre; breathe in, pinch the nose, slightly bend the head backwards, and gently blow out to increase the pressure in the throat until the ears 'pop'. If that fails, try swallowing instead of blowing; this will feel temporarily worse, but the next Valsalva movement may then work. Do not blow too hard.**

Hay Fever: Hay fever can cause the same inability to clear the ears as does infection, but of course there is no infective agent present. With luck, nasal steroid sprays will 'shrink' the lining of the eustacian tubes and permit clearing the ears. Anti-histamine sprays are dubious before flying as they may cause drowsiness, whilst anti-histamine tablets (even the 'non-sedating' ones) should NOT be used before flying.

Blood sugar levels: Sugar (glucose) is the only form of nutrition used by the brain, so clearly having a blood sugar level in the normal range is critical to flying. This means that one should **arrive at the Field properly fed, and continue to 'graze' throughout the day.** Hypoglycaemia (low blood sugar level) is not uncommon in daily life; the symptoms are **shakiness, nervousness, increased heart rate (maybe palpitations) and fainting.** A large food intake at lunch time can make people sleepy and should be avoided. Carry snacks in the glider, **and graze regularly, not waiting for hunger to prompt you. Simple sugars (glucose, fructose in lollies) provide a sudden rise in blood sugar levels, often followed by a sharp drop as the body over-produces insulin to get the sugars into the cells, and may thus be counter-productive. Better a complex carbohydrate plus some fat (as in a 'muesli bar') to give a steady rise, long plateau, and slow fall. Bananas are good and come conveniently packaged.**

Diabetes: Diabetics cannot control their own blood sugar levels naturally, the level always being too high unless they are over-treated. Some require insulin by injection, some need tablet medication, whilst some need only rigid dietary control. **Whilst a diabetic pilot needs to be under the care of both a diabetic specialist and an aviation medicine specialist, even insulin dependent diabetics can fly in high performance aircraft. Diabetics should seek specialist care immediately they wish to start gliding, but should not feel barred from the sport.**

Angina and Heart Attacks: Coronary artery disease is very common; it is known that many commercial pilots with significant coronary artery disease but as yet without symptoms are carrying airline passengers, which is a major reason whilst all aircraft carrying more than a dozen or so fare-paying passengers must have two or more pilots qualified on type. **For the glider pilot with angina, or having recovered from a heart attack, the outlook is not bleak but just needs to be considered carefully. The key factor is the likelihood of sudden incapacitation.** If this is felt unlikely (and the time that the condition has been present without causing problems is vital in deciding that) then a person may fly as pilot in command. In this, general practitioners countersigning gliding medical certificates are guided by the NZTA rules applying to those driving on the roads with passengers. Glider pilots are lucky in this respect as far more stringent rules apply to powered pilots who may need very expensive medical investigations in order to prove their safety to act as pilot in command. In gliding, if angina is made worse by flying, then it is very unwise to continue to fly solo and even more foolhardy to take a passenger who is unable to safely land the glider should incapacitation occur**. Should angina occur at times, for example on strenuous exercise but not in the air, then with your (aviation) doctor's agreement, acting as pilot in command is possible.**

Alcohol and illegal drugs (including legal performance enhancing drugs)

This section could be reduced to a single sentence: **gliding whilst under the influence of alcohol or drugs is illegal and foolhardy in the extreme.** Sadly those who do so seem to ignore the obvious, which places a duty on all other glider pilots to speak out if they have the slightest suspicion about other club members. Gliding has had very little exposure with this problem and club members must all continue to be vigilant and keep it that way.

Alcohol: The effects of alcohol are insidious as one of its major effects is to reduce inhibition. Thus once a person has had some alcohol, it is very common for the previously self-set sensible limit ("I'll just have one tonight") to be revised upwards ("Let's have another...."). Whilst there is a limit for the blood level of alcohol above which driving a vehicle on the roads becomes illegal (80 milligrams alcohol per 100 millilitres of blood), there is little scientific reason behind this arbitrary figure. Different people, and the same person in different circumstances, require vastly different alcohol intake to exceed this figure. Additionally, there is little correlation between blood alcohol level reached and reduction of psycho-motor performance (capability) of the person. **Thus the only intake of alcohol that can be considered compatible with flying is zero for at least 12 hours before flying, and possibly longer.**

Whilst the measurable blood level of alcohol should have returned to approximately zero after twelve hours (there is always some in the blood resulting from our normal metabolism of carbohydrates), the effects can last much longer. **Alcohol diffuses into the fluid within the organ of balance (vestibule), diluting the fluid in the semi-circular canals and making us more susceptible to disorientation ('the room spinning around'). It diffuses out over a period of time, and is thus still there when the blood level is back to zero. The balance (vestibular) problems persist for some time after. Apart from the increased liability to disorientation, susceptibility to hypoxia is also increased and thus may become significant at altitudes well below 10,000', resistance to 'g' loadings reducing also. Very importantly, our ability to carry our procedures is compromised for longer periods; a scientific study found that commercial pilots in a simulator, with blood alcohol levels back to the normal background figure of 0.01% after being raised by drinking, the procedural error rate was 68%. Two thirds of them made errors.**

Smoking

Smokers may well be unaware of the reduction in their capabilities even on the ground, and as with alcohol there is a common tendency to dismiss even what is obvious. **Smoking has many effects on pilots but the most important one is via the carbon monoxide inhaled.**

Although the proportion is small, **carbon monoxide has a great affinity for haemoglobin, displacing the oxygen that should be carried.** If a person is breathing just 0.5% carbon monoxide, that will displace 50% of the oxygen that would otherwise be carried, and the person would be close to death even at sea level. **Carbon monoxide in cigarette smoke remains present in the blood for days after the last cigarette** (doctors use a carbon monoxide monitor as a 'lie detector' to prove to patients that their claim to have stopped smoking is untrue) and **very obviously increases a person's susceptibility to hypoxia, symptoms occurring at a lower altitude, as well as reducing their exercise tolerance at all altitudes in what is a physically demanding sport. Fatigue will set in sooner, endangering the landing.** The lack of inflammable fuel in a glider may encourage the delusion that smoking does not compromise aviation safety. It does, markedly.

10) PASSENGER FLYING – the nervous passenger

New Zealand CAA Part 115 regulations now allow only those who have an interest in joining the Club to pay for trial flights, a flight with an instructor during which some instruction is given and the person encouraged to continue with gliding. Thus a member of the public can no longer pay for a 'joy ride' just for the fun of it. However, **any QGP with a passenger rating, authorised by the duty instructor, can fly a friend.** Some of these passengers may not be true volunteers, and may be quite nervous. How you conduct the flight makes the difference between a potential recruit to our sport and a person who will never want to fly again, perhaps spreading negative publicity.

Get your passenger to the Club in good time to witness several launches; ideally even before the day they will fly. **Explain the events and answer questions.** Debunk the idea that gliding is smooth, effortless and quiet. To a new participant, the take-off and tow are not 'smooth and quiet'. The steep approach and landing is uncomfortable and very noisy as the airbrakes are deployed. To you, that bump is lift, to them it is turbulence, and they are yet to be convinced of the structural strength of the machine. After all, it has no engine, so it must crash – all other aircraft do. And what if the wind stops? Your enthusiasm is essential, but you must see their point of view as well.

Ideally **sit them in a glider well before your slot and explain everything.** Make sure they bring a camera. Go through the possible flight profile, cable breaks included (that is no time to have a panicking passenger). Ask them if they want a 'sled ride' or if they would like you to soar, warning them that control movements will be frequent if so. Warn them that the landing approach is steeper until a (low) round-out, and that the brakes will be deployed. Perhaps delay the flight until a more stable day if they are apprehensive. **Tell them to warn you immediately if they feel queasy**; it is not brave but silly to 'tough it out'. Tell them what you will do if they feel unwell.

During the flight, **keep talking about what is happening** (as an aside, most instructors like pupils to do this too; it is reassuring for them to know that you are monitoring the airspeed on approach and intending to round out even if you are struggling) but encourage (and expect) a two-way conversation**. A quiet passenger is probably close to their limit.** If it is necessary to cut the flight short, cease any unnecessary manoeuvring and get them to look at the horizon. There is a conflict of information reaching their brain (see 'orientation') so try to reduce that disparity. Do wide sweeping turns to position for landing, with a lot of gentle airbrake use rather than sudden full applications except when required on final approach. Whilst it might be good to give a passenger a sick-bag before the flight, this has rather negative connotations. It is probably better to have one readily available for you to pass to them (tell them not to turn their head). Warn Glider Base you are "returning early". Saying "the wimp has ruined my flight" does not make friends in the other seat. Once on the ground, have that bag instantly ready for a while but ideally **let the person sit in the cockpit, canopy open, for a while.** The act of moving the head when clambering out can be the final straw. If they do vomit, rinsing the mouth with water is very helpful. This is not the time for the fizzy drink that all gliding caravans seem to stock.

A sympathetic and thoughtful approach may mean a new member, but it is possible to put even the toughest character off flying for ever if you show off.

11) EMERGENCIES

Parachutes

There seems to be an established convention that single-seat gliders are flown wearing a parachute, twins not, although in competition all pilots (and passengers) must wear parachutes. Twins are generally flown on shorter training flights, singles more adventurously in competition and at greater heights, **but when twins are operated high enough for a parachute to be effective, it makes sense to 'go equipped'. Competent parachutists have survived emergency abandonments from as low as 1000'**

As with any emergency procedure, the time for familiarity and practice is when calm on the ground, not in the air when immediateuse is imperative. A delayed or fumbled exit is unlikely to be life-saving. Formal instruction by a parachute instructor (a useful interclub activity in its own right, offering a glider launch gratis in response) should be complemented by self-tuition; **always get out of the glider after each flight with your parachute still attached,** practising as if for real, noting the relationship of the wing as well. An exit in anger should be a lot easier and quicker, aided by adrenalin and the lack of a cockpit canopy. It needs to be – time is short. Taking even a one-off tandem jump will mean that once the canopy has opened in your emergency descent, you can almost relax; you've done the rest of it before.

Remember the sequence:
LOOK for the handle ('D-ring').
GRIP the handle (both thumbs through the 'D-ring').
PULL the handle (actually it's a push, to your full arm's length).
ARCH your back (helps stabilise you in the free fall until the parachute opens).

Some parachutes have a long slender pack which you partially sit on. This provides extra cushioning should you have a very heavy landing, but, if you are tall, the compact pack behind you may be the only option. Comfort is relative in a glider, but aim for what is the best for you. Examine the parachute as you would DI a glider – your life may depend on it**. Check the packing date. As a**

parachute nears its repacking date, the fabric is beginning to adhere to itself, and opening takes appreciably longer according to the experts. If it is out of date it may take too long. The aircraft PLB is of little use in the crashed glider so attach it to the parachute harness. It will usually fit over the chest strap. The straps should be tight enough to make walking difficult. The time for which they need to be correctly adjusted is when you are hanging under the canopy, and then loose straps are a worry even if not much of a danger. However, when the canopy opens, loose straps can painfully thwak your thighs.

You will probably have little time under the canopy to enjoy the experience, and emergency canopies are not easily steerable anyway, but try pulling on either raiser to see if you have any form of directional control or look for steering toggles attached to the raisers. If possible, aim to turn so you face into wind to land as most parachutes impart forward motion and this cancels some of the wind speed. **Hold your legs together firmly, knees slightly bent. Twist slightly so that one hip is facing the direction of travel at touchdown**. Perfection is to allow your legs to fold as they absorb much of the shock, followed by a forward roll to one side and then, then lying on the ground, spill the air out of the canopy (a fifteen knot wind will drag you under a full canopy) by pulling on the lower cords. Perfection is unlikely to be achieved!

If going into trees, hold the legs even firmer together and use one arm/hand to shield your face, above all your eyes. Keep one hand firmly on a riser so you do not pitch forward but 'spear' feet first into the foliage. Unless you are sure the ground is very close, think extremely carefully (and at length) before releasing yourself from the harness. You are out of immediate danger, but your judgement will be in tatters and might lead to wrong decisions if rushed. Rather stay in the tree until help arrives than fall and sustain serious injury.

If going into the water, do not panic; this is the softest arrival of all although good swimming ability is reassuring. **DO NOT release from the harness until your feet at least are wet.** Delay is not serious. Over open sea, pilots have fallen from parachutes to their deaths as height judgement there is difficult. Do not panic if the canopy falls on you. **It is entirely possible to breathe under a parachute canopy,** just by lifting a small area in front of your face. Military pilots practice this regularly, albeit usually in a swimming pool. Do not thrash about – this will entangle you in the lines. Slowly and deliberately follow a seam and you will reach an edge. If this happens to be the hole in the centre, at least you know which way to go now.

Survival after accidents

<u>Crash imminent:</u> Even when a crash is inevitable, there is still the opportunity to influence the outcome for the best. Your priorities are as always **aviate, navigate, communicate.** Aviating at this crucial moment means to fly the glider all the way into the crash. Do not give up. Try to steer the nose between big trees, rocks or whatever. Just before the moment of impact, get the feet back off the rudder pedals and put one hand over your face. A last pull on the stick might get you over a rock – better to stall over the rock than fly into it fast. **Remember the adage that *it is better to hit the far hedge at slow speed than the near hedge at flying speed*. A lot of your training has concentrated on touching down at an exact aiming point. Practice this with EVERY routine landing.** Just possibly it is better to stay in, and even flatten, a spin near the ground, but it takes a calm person to assess that. A spiral dive, however, is lethal so try to recover. There is no navigating left to do unless you include boulder avoidance, but even a brief communication might be helpful. If you are on an ATC frequency as opposed to a chat frequency, and in contact, then your transmission has been recorded. Even if "Mayday" is not heard at the time, if an aircraft is missing the relevant tapes are replayed and may yield important information such as the exact time to relate to transponder traces etc. The single word "Brace" (the pilot remembered to press the transmit button as he warned his crew) has initiated a full and successful rescue operation. Having a passenger aboard brings extra responsibilities. Remember to tell them your thought processes so they are prepared, remind them to tighten their straps fully, to cover their eyes and support their head. Look after their welfare after the event.

Immediate post crash actions. After the impact you may be unconscious, but you will not know how long for, nor perhaps even that you were knocked out at all. Even without a head injury, your judgement will be very poor in the immediate post-crash situation. Fortunately gliders are most unlikely to catch fire (unless you hit power cables!) so there is probably no need for immediate action. Better by far to recover a bit and only act when your brain seems to have cleared. Acting too rapidly has led to added injury or even death, such as by undoing straps and falling onto the head, fatally. It may well be best just to stay strapped in and await help. Possibly you can use the radio, and might contact a passing aircraft (on 121.5 MHz if you can select it) to relay for you.

Survival longer term. Survival in a hostile terrain (mountainsides etc.) is a fascinating topic but has no place here. Suffice to say that the mantra of priorities is: **PROTECTION, LOCATION, WATER, FOOD** in that order. If on high ground or if night is near, death by hypothermia is a real possibility. **Your open parachute can provide valuable insulation, and getting out of the wind is important.** As to location, again a deployed parachute greatly increases your visibility to searchers. Perhaps that radio will work if you try again. This is a time to be thankful if you have been sending out regular position reports or have good 'flight following' procedures in place. In the South Island, 'SPOT' trackers are now required to be carried. If you have come down in wooded country, perhaps find a clearing, but in general do not leave the crashed glider unless you have to as it is your best chance of being seen by those searching for you. **You should have a first-aid kit, water and food and a warm, windproof garment with you** on all cross-country flights. **Head cover (beanie, balaclava) is vital as much heat loss is from the head.**

Rest assured that New Zealand has an efficient Search and Rescue organisation and you are very unlikely to have to spend a night out. For a brutally honest account of how human factors (plus some unlucky meteorology as a secondary factor) caused a crash, and how he coped with the aftermath, read Giorgio Galetto's account of his accident in the French Alps (Gliding International, Jan-Feb 2013). Remember that at the time of his crash he was rated the best soaring pilot in the World. He carries marine distress flares. These could be useful in a remote location, but the thought of one set off accidentally in the cockpit is not reassuring. If an aircraft appears, use the flare (or signal mirror – much safer to carry in an aircraft) when you are in the forward sector of the pilot's vision. Leaving it until the aircraft is closer but you are to one side of it is a worse option, especially if the aircraft just happens to be in the area and is not actively searching for you.

<u>First aid</u> You are participating in a sport that does have risks; for some that is part of its attraction. By law there is a first aid kit (usually pretty basic) in every glider, and hopefully in your caravan or clubhouse too. This heading is not the place for any first aid instruction, but merely a convenient time to suggest that if you are not first aid qualified, then you should seriously consider taking at least a basic course. It will stand you in good stead at all times, not just 'at the Field'.

CONCLUSION

Gliding is a wonderful sport. As with any such activity, the more you know about both the core and peripheral aspects of the sport, the faster you will learn and the more pleasure you will get. It is not only possible but very advantageous to study for and take the QGP exams early on. It is not a matter of 'getting them out of the way', it is a positive help in progressing. However, once that coveted Qualified Glider Pilot certificate is in your hands, revisit all five sections of the course. You are now out of the training tunnel, and an independent pilot pushing your boundaries. More than ever, you need the knowledge above (and in the other study subjects). The organised list of exercises to be ticked off for each certificate must be replaced by a desire to learn more, continually improve, and of course an occasional flight with an instructor in addition to the biennial flight review.

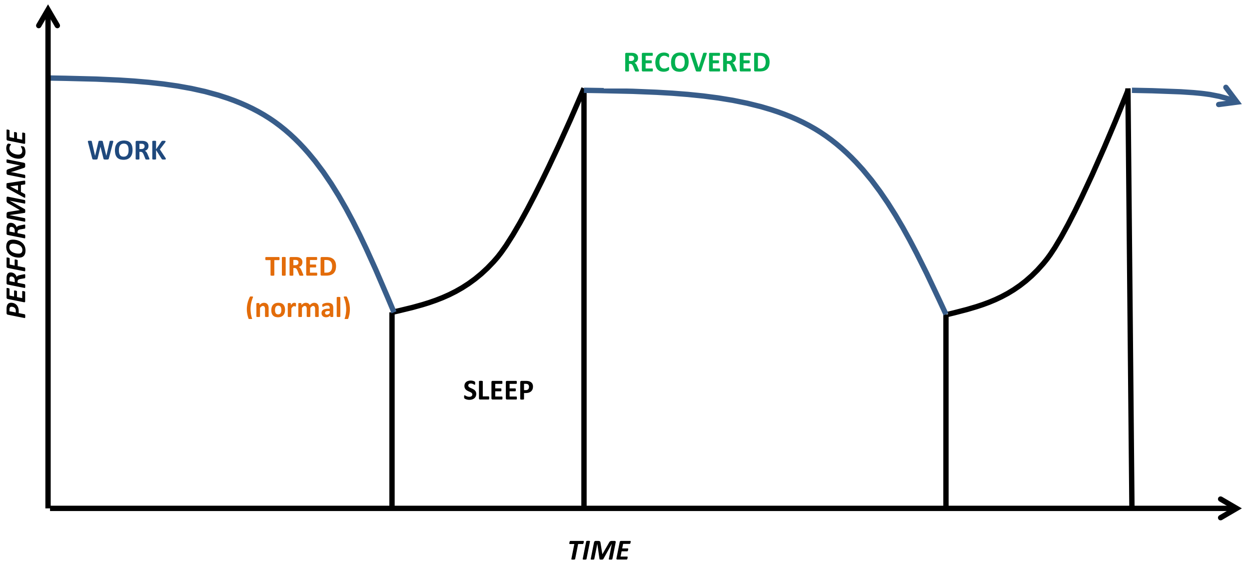
Study the accident/incident summaries that appear in the gliding magazines from time to time. Most have significant human factors amongst their causes. This includes all during outlandings; a pilot should not get into the position where he has to land in a difficult paddock, but even if that happens he should be able land in a confined space. There is certainly nothing wrong with the glider initially, and others would have made a safe landing. It is the pilot who is the cause; a human factor.

Good Luck, and safe flying.

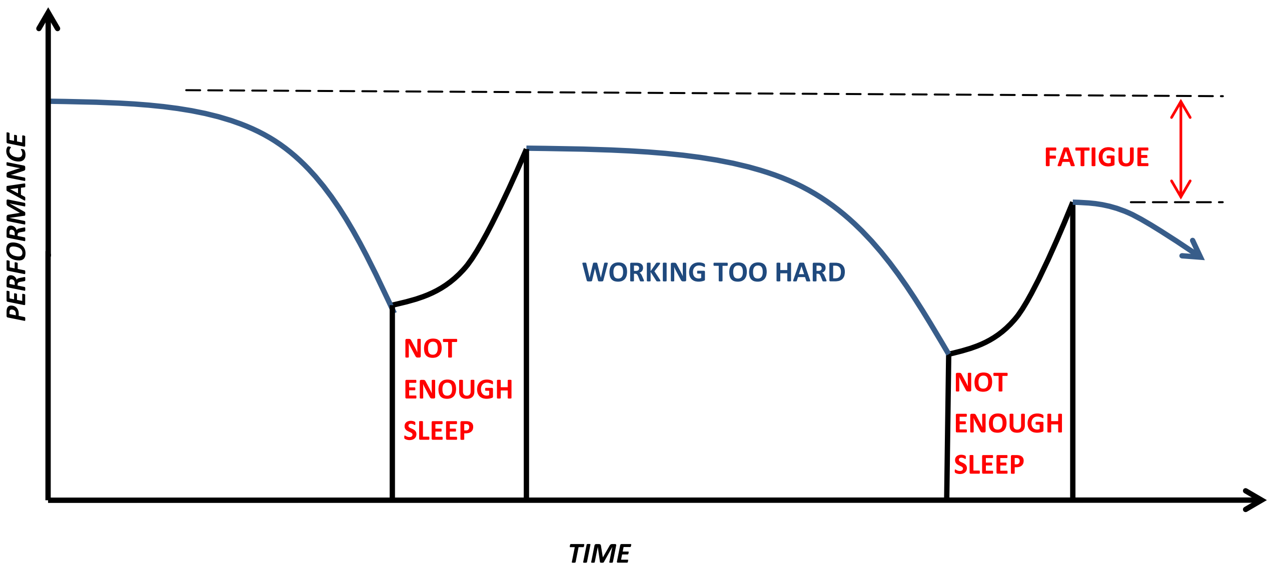
Jonathan Pote, Auckland Aviation Sports Club, May 2013 jonpote@hotmail.com

APPENDIX 1 RECOVERY FROM FATIGUE

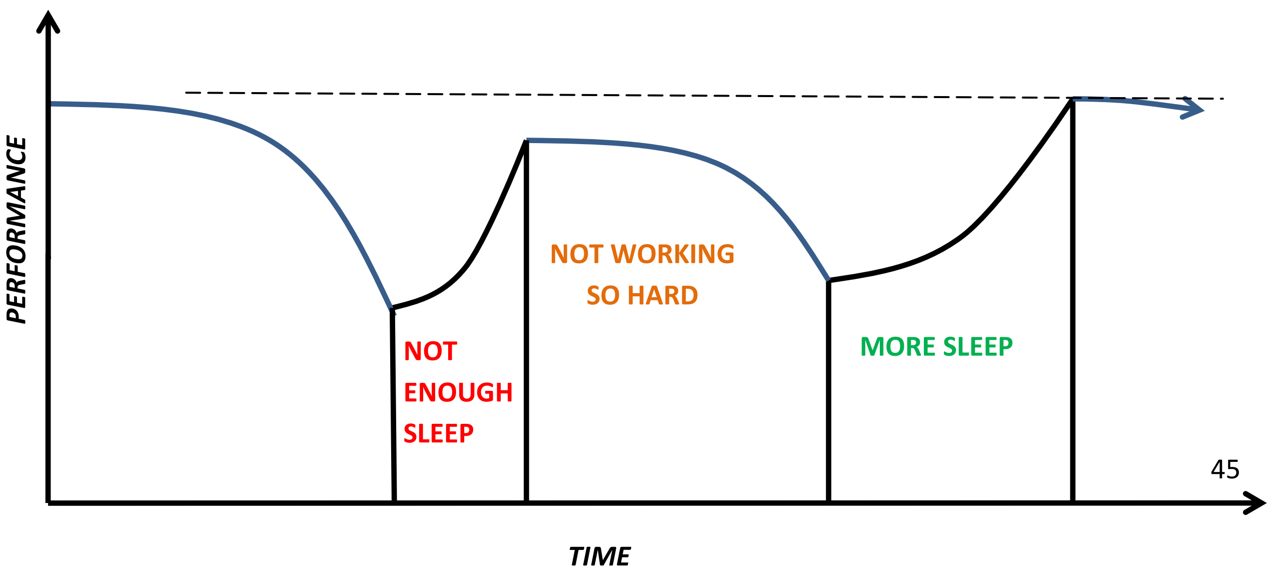
1. NORMAL PATTERN



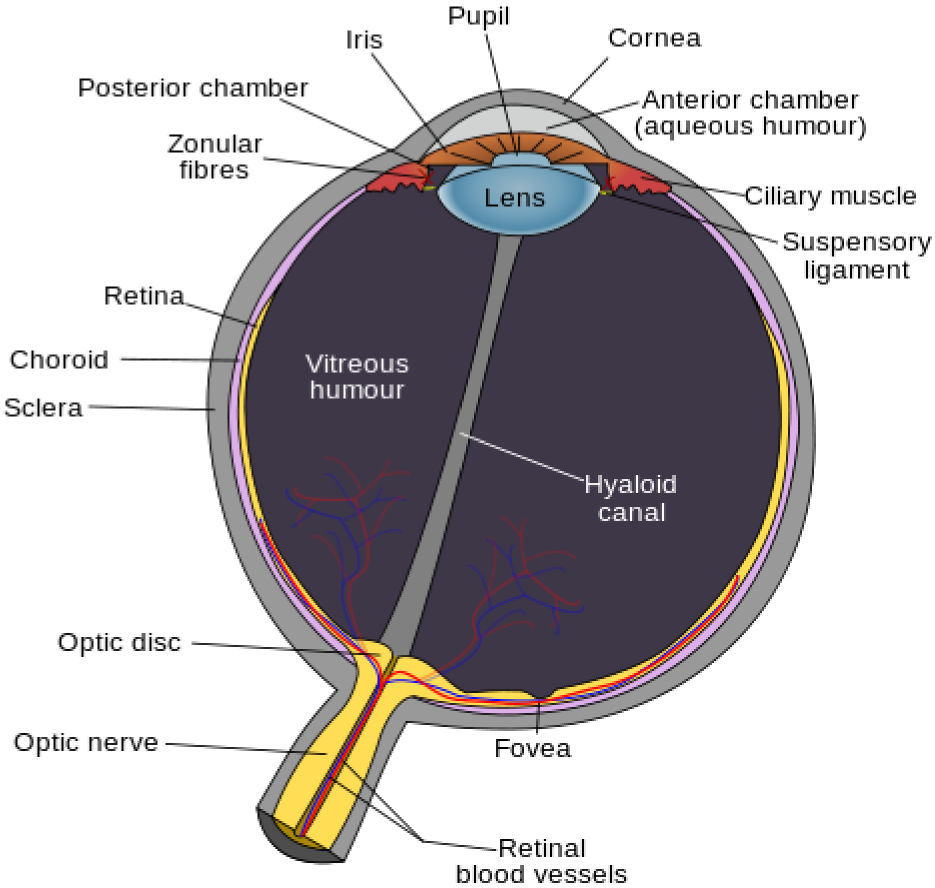
2. FATIGUE DEVELOPS



2. FATIGUE OVERCOME



APPENDIX 2 ANATOMY OF THE HUMAN EYE



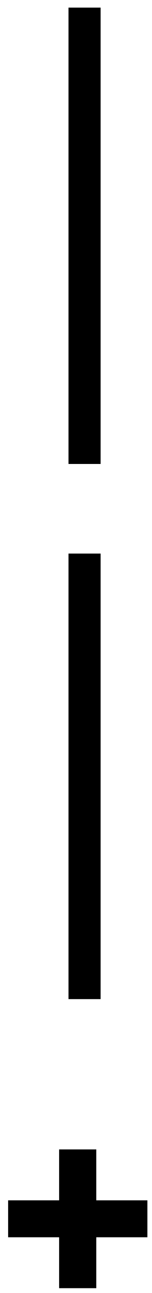
APPENDIX 3 VISUAL ILLUSIONS – BLIND SPOT #1

[To see the illusion, you must view this page in landscape – either rotate the page clockwise in your viewer or print it out]

Cover the left eye and, while focusing the right eye on the cross, move the page slowly towards the head and then away from the head. Notice what the eye sees regarding the "dot"

APPENDIX 4 VISUAL ILLUSIONS – BLIND SPOT #2

[To see the illusion, you must view this page in landscape – either rotate the page clockwise in your viewer or print it out]



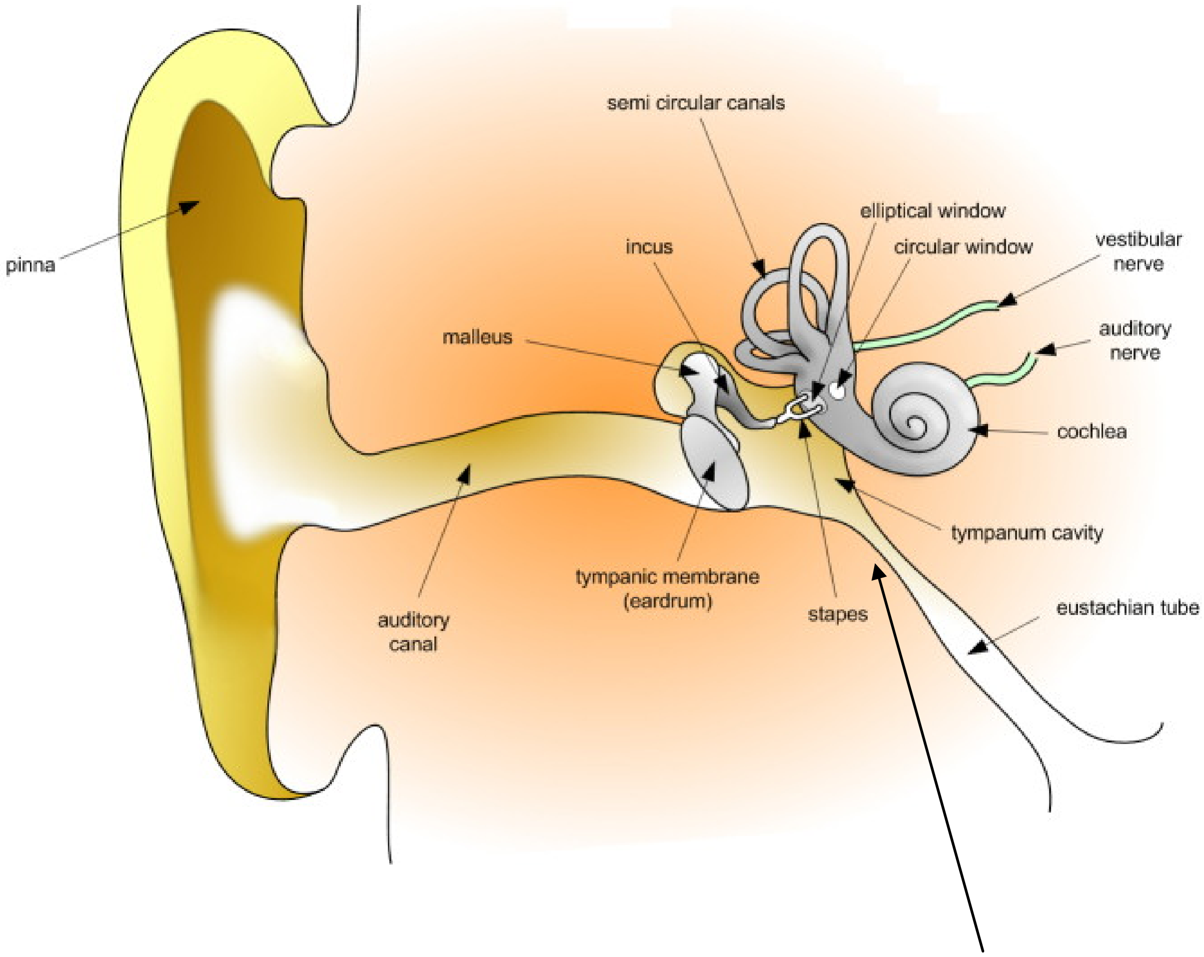
Cover the left eye and, while focusing the right eye on the cross, move the page slowly towards the head and then away from the head. Notice what the eye sees regarding the "gap"

APPENDIX 5 TIME LAPSE BETWEEN LOOKING & RESPONDING

PROCESS		TIME FOR EACH PHASE	TOTAL TIME LAPSE
Looking	Is there something out there?	0.2 sec	0.2 sec
Seeing	Yes, there is definitely something out there!	0.3 sec	0.5 sec
Recognising	It is another glider … a Twin Astir!	1 sec	1.5 sec
Evaluating	It is coming this way … I need to turn, Now!	3 sec	4.5 sec
Responding	Manoeuvring to avoid collision	3 sec	7.5 sec

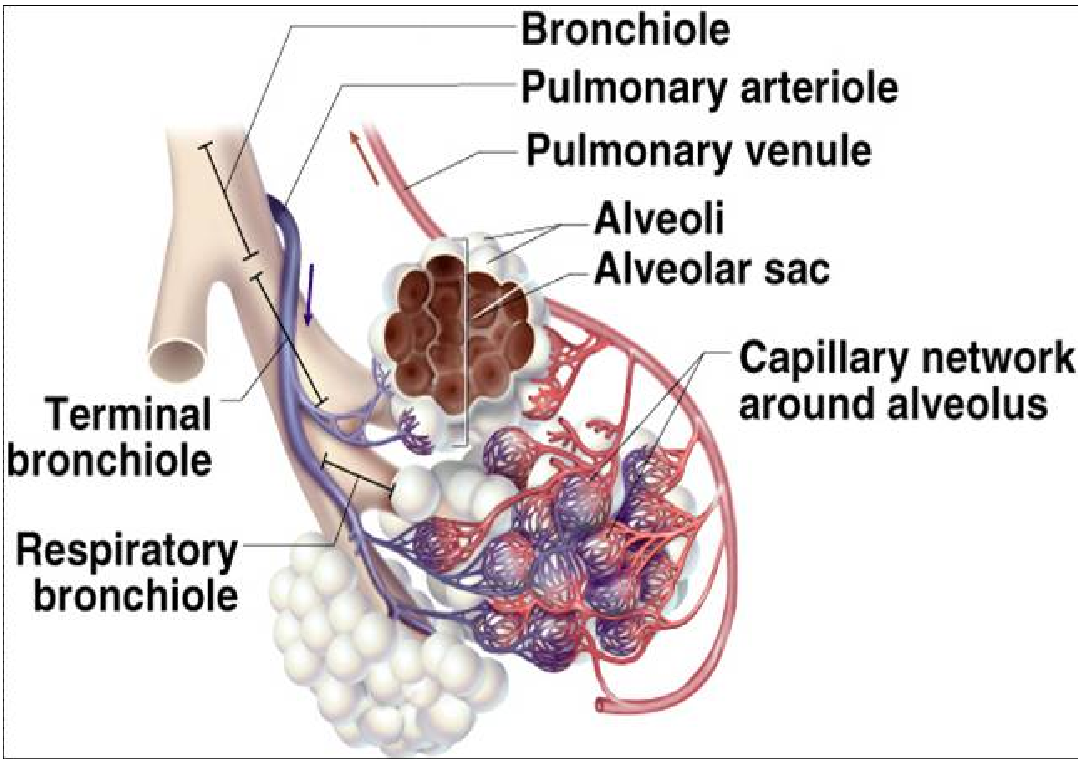
APPENDIX 6 ANATOMY OF THE HUMAN EAR

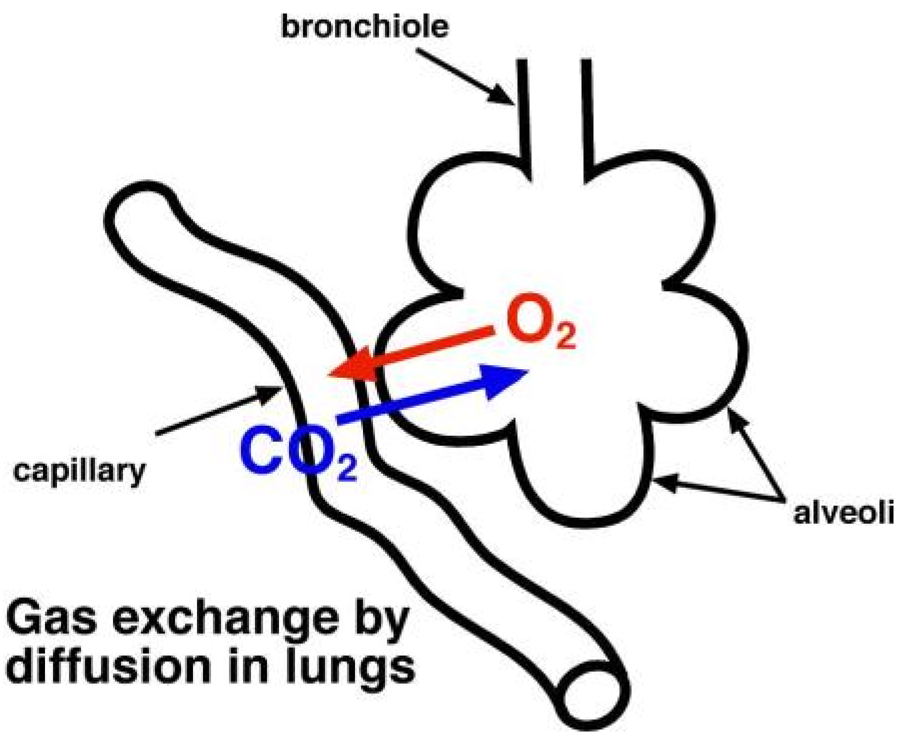
[The otoliths (utricle & saccule) are not shown – see page 15]



Note the narrowing of the Eustachian Tube, which makes it prone to blockage

APPENDIX 7 ALVEOLI OF THE LUNG





APPENDIX 8 TIME OF USEFUL CONSCIOUSNESS

TIME OF USEFUL CONSCIOUSNESS		
Altitude	Sitting	Moderate Activity
18,000 ft	20-30 min	10-15 min
21,000 ft	10 min	5 min
25,000 ft	3 min	2 min
28,000 ft	1.5 min	1 min
30,000 ft	1.25 min	45 sec
35,000 ft	45 sec	30 sec
40,000 ft	30 sec	18 sec
43,000 ft	15 sec	9 sec

Human Factors: Mock exam

Gliding New Zealand
Qualified Glider Pilot Certificate
Human Factors Examination

Note: In this mock exam, the questions largely follow the order of the syllabus to aid looking up the relevant text after you have sat the exam.

1) Exposure to stress for a long time leaves us fatigued. Recovery from fatigue requires:
a) Eating high protein food and using caffeine based drinks to help stay awake longer.
b) Rest and sleep.
c) Working harder and adapting to less rest time.
d) All of the above.

2) Approaching to land on sloping ground can create the illusion that:
a) your speed is too high for the angle of approach.
b) you are low if the slope is uphill so you get too high on final approach.
c) you are too high if the slope is uphill so you may end up too low and undershoot.
d) you are too high if the slope is downhill so you get too low and undershoot.

3) The minimum time necessary to avoid a collision once another aircraft enters you field of vision may be:
a) two seconds.
b) five seconds.
c) over four seconds.
d) over seven seconds.

4) The blind spot is:
a) a circular portion of the visual field of which only one eye forms an image.
b) behind and directly below your glider.
c) where an object is invisible to both eyes.
d) interesting, but of no practical importance to glider pilots.

5) Landing with water droplets on the canopy is hazardous because:
a) the eyes focus on the droplets which reduces your depth perception and this often leads to heavy landings.
b) the eyes cross focus on the droplets causing possible double or blurred vision.
c) droplets magnify the prismatic colour displacement which may induce flicker vertigo.
d) the streaming droplets create a false peripheral horizon which can induce the leans.

6) What is the most important body system for keeping the pilot orientated?
a) The balance organs of the inner ear that provide our sense of balance.
b) The visual system that provides our horizon reference.
c) The nervous system that allows us to fly "by the seat of the pants".
d) The intestinal system that allows us to fly according to "the gut feeling".

7) Orientation when flying:
a) is based largely on sight, aided by the vestibular apparatus.
b) improves once you are more experienced, e.g. a Qualified Glider Pilot.
c) requires you to disregard what you see.
d) is simple when gyro instruments are fitted even if you are not very familiar with them.

8) You may fly into cloud if in a suitable area:
a) if in stable flight (speed and direction constant).
b) in a glider suitably equipped and if you are trained and current in instrument flying.
c) if it is small (just a few hundred metres across/deep horizontally and vertically).
d) from beneath to capitalise on good lift.

9) The 'Oxygen paradox' is:
a) feeling worse on 100% oxygen via a mask than when breathing air because too much oxygen is poisonous.
b) feeling worse briefly when commencing supplemental oxygen and thus suspecting impurities, or making inappropriate actions immediately after commencing supplemental oxygen.
c) that nasal cannulae are better than a mask despite what you may suppose.
d) the fact that using oxygen below 9,000' tends to make accurate flying harder.

10) The symptoms of hyperventilation may include:
a) rapid breathing, dizziness, faintness, tremors, clumsiness and anxiety.
b) over confidence, loss of self criticism, decrease in colour vision and peripheral vision.
c) pain in the middle ear and possible stomach cramps.
d) all of the above.

11) If you have an oxygen system:
a) your local welding firm should have supplies of pressurised oxygen.
b) you should carry the manual so you can refer to it if you think you have a problem.
c) it must be refilled only with certified aviation oxygen.
d) a dive centre can refill your bottles to the required pressure.

12) What warning do you have as you approach your threshold of tolerance to positive 'g'?
a) You start "greying out" as the blood flow to the eyes is reduced and your peripheral vision diminishes.
b) None, unless you have a G meter fitted to your glider.
c) You start "redding out" as excess blood rushes to the head and engorges the eyes with blood.
d) You get a tingling in your toes as the nerve endings are compressed.

13) Negative 'g':
a) is harmless, as you never become unconscious.
b) causes the brain to be starved of blood supply.
c) does not occur in a spin.
d) is unpleasant and may cause inappropriate action.

14) If a pilot becomes excessively cold (hypothermic) on a long, high flight:
a) recovery is slow, and he should not fly again that day.
b) a hot drink laced with rum will see him fit to fly again if dressed more warmly.
c) then with a run around to warm up plus warmer clothing he can fly again the same day.
d) he is not suited to gliding and should find another sport.

15) Hypoglycaemia (low blood sugar level) can be a problem when flying:
a) Diabetics are forbidden to fly.
b) You should carry snacks of complex carbohydrates and 'graze'.
c) You should carry a supply of glucose sweets; these raise the blood sugar level rapidly.
d) You should eat a large meal before you launch. This keeps the sugar level up for hours.

16) If you 'fail' the IMSAFE self-test, then:
a) take it easy whilst others get in a launch or two (maybe take a couple of paracetamol) and re-assess yourself in an hour or so.
b) cancel any personal piloting for that day.
c) evaluate the others around and see if you are actually worse that they appear to be.
d) discuss it with the Duty Instructor; he can clear you to fly if he is happy.

17) Why is flying with an upper respiratory tract infection not recommended?
a) Because you may damage your middle ear or aggravate sinus disorders because of an inability to equalise the pressure in these cavities.
b) Because a blocked nose may cause hyperventilation and possibly the chokes.
c) Because a cold will impair your hearing and radio calls may be missed.
d) because subtle pressure changes that help you detect lift and sink are not detected.

18) Chest pain prevents a person acting as pilot-in-command:
a) unless he has been symptom free for a month.
b) unless he can carry out everyday activities whilst experiencing the pain.
c) unless cleared by a doctor with experience in Aviation Medicine.
d) ever again.

19) During a landout, the following are usually good ways to estimate the height at which to commence the circuit:
a) The altimeter, as you set it before take-off.
b) Barns and trees.
c) The overall picture of trees, buildings, vehicles and livestock.
d) The angle to the aiming point.

20) "Constant angle, constant danger" is a reminder that:
a) if you keep a constant angle of bank in a thermal for too long, you can become disorientated when finally levelling the wings.
b) if another aircraft is on a collision course with you, there is no relative movement in your visual field and you are less likely to see it.
c) as you approach the ground, you must begin to raise the nose.

d) in the circuit if you keep a constant angle to your aiming point you will climb and possibly stall towards the end of the downwind leg.

Correct answers, GNZ Human Factors mock exam:

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

11	12	13	14	15	16	17	18	19	20
C	A	D	A	B	B	A	C	C	B