Chapter 9: Aeromedical Factors

Introduction

As a pilot, it is important to stay aware of the psychological and physical standards required for the type of flying performed. This chapter provides information on medical certification and on aeromedical factors related to flying activities.

Most pilots must have a valid medical certificate to exercise the privileges of their airman certificates. Balloon pilots exercising student, sport or private pilot privileges, and commercial balloon pilots conducting flight instruction are not required to hold a medical certificate. Balloon pilots exercising commercial pilot privileges for operations other than flight instruction are required to hold at least a second-class medical certificate.

Some operations conducted outside the United States may require the balloon pilot to have a medical certificate when it is otherwise not required in the United States. For example, United States certificated balloon pilots participating in events in Canada may be required to hold a medical certificate in order to carry passengers. In this case, it would be wise to check with the appropriate authorities to determine the requirements for specific operations. Title 14 of the Code of Federal Regulations (14 CFR) part 67 covers medical certification of pilots. Aviation medical examiners (AMEs) may be found using the FAA's Find an Aviation Medical Examiner (AME) website.

Environmental & Health Factors Affecting Pilot Performance

A number of health factors and physiological effects can be linked to flying. Some are minor, while others are important enough to require special consideration to ensure safety of flight. In some cases, physiological factors can lead to in-flight emergencies. Some important medical factors that a pilot should be aware of include hypoxia, hyperventilation, middle ear and sinus problems, motion sickness, stress and fatigue, dehydration, and heatstroke. Other subjects include the effects of alcohol and drugs, anxiety, and excess nitrogen in the blood after scuba diving.

Hypoxia

Hypoxia means "reduced oxygen" or "not enough oxygen." Although any tissue will die if deprived of oxygen long enough, the main concern is usually with getting enough oxygen to the brain, since it is particularly vulnerable to oxygen deprivation. Any reduction in mental function while flying can result in life-threatening errors. Hypoxia can be caused by several factors, including an insufficient supply of oxygen, inadequate transportation of oxygen, or the inability of the body tissues to use oxygen. Four forms of hypoxia based on their causes are: hypoxic hypoxia, hypemic hypoxia, stagnant hypoxia, and histotoxic hypoxia.

Hypoxic Hypoxia

Hypoxic hypoxia results from insufficient oxygen available to the body as a whole. The reduction in partial pressure of oxygen at high altitude can cause a pilot to experience this type of hypoxia. As an unpressurized aircraft ascends during flight, the percentage of atmospheric oxygen remains constant, but a reduced number of oxygen molecules enter the lungs and pass between the membranes in the respiratory system.

Hypemic Hypoxia

Hypemic hypoxia occurs when the blood cannot take up sufficient oxygen. Causes of this form of hypoxia include reduced blood volume from severe bleeding or certain blood diseases, such as anemia. Carbon monoxide poisoning causes this type of hypoxia. Hemoglobin, the blood molecule that transports oxygen, becomes chemically unable to bind oxygen molecules if exposed to carbon monoxide. Hypemic hypoxia can also occur after a blood donation. While blood volume normalizes quickly following a donation, restoring the lost hemoglobin can take several weeks. Although the effects of the blood loss seem slight at ground level, blood donation can create a pilot flight risk during the recovery period.

Stagnant Hypoxia

Stagnant means "not flowing." Stagnant hypoxia results when the oxygen-rich blood in the lungs is not moving, for one reason or another, to the tissues that need it. One form of stagnant hypoxia is an arm or leg "going to sleep" because the blood flow has accidentally been shut off. This kind of hypoxia can also result from shock, the heart failing to pump blood effectively, or a constricted artery. Cold temperatures can also reduce circulation and decrease the blood supplied to extremities.

Histotoxic Hypoxia

The inability of the cells to effectively use oxygen is defined as histotoxic hypoxia. "Histo" refers to tissues or cells, and "toxic" means poison. In this case, plenty of oxygen is being transported to the cells that need it, but they are unable to make use of it. This impairment of cellular respiration can be caused by alcohol and other drugs, such as narcotics and poisons. Research has shown that drinking one ounce of alcohol can equate to an additional 2,000 feet of physiological altitude. There are other issues concerning the use of alcohol in relation to flying in general; those will be discussed later in this chapter.

Symptoms of Hypoxia

High altitude flying can place a pilot in danger of becoming hypoxic. Oxygen starvation causes the brain and other vital organs to become impaired. One noteworthy attribute of the onset of hypoxia is that the first symptoms are euphoria and a carefree feeling. With increased oxygen starvation, the extremities become less responsive and flying becomes less coordinated. The symptoms of hypoxia vary with the individual, but common symptoms include:

- Cyanosis (blue fingernails and lips).
- Headache.
- Decreased reaction time.
- Impaired judgment.
- Euphoria.
- Visual impairment.
- Drowsiness.
- Lightheaded or dizzy sensation.
- Tingling in fingers and toes.
- Numbness.

As hypoxia worsens, the field of vision begins to narrow, and instrument interpretation can become difficult. Even with all these symptoms, the effects of hypoxia can cause a pilot to have a false sense of security and be deceived into believing that everything is normal. The treatment for hypoxia includes descending to lower altitudes and/or using supplemental oxygen. Supplemental oxygen is required for certain operations above 12,500 feet mean sea level (MSL). (See 14 CFR part 91, section 91.211.)

All pilots are susceptible to the effects of oxygen starvation, regardless of physical endurance or acclimatization. When flying at high altitudes, it is paramount that oxygen be used to avoid the effects of hypoxia. The term "time of useful consciousness" describes the maximum time the pilot has to make rational, life-saving decisions and carry them out at a given altitude without supplemental oxygen. As altitude increases above 10,000 feet, the symptoms of hypoxia increase in severity, and the time of useful consciousness rapidly decreases. Many pilots have established an altitude lower than the required 12,500 MSL as their personal "do not exceed without oxygen" limit. All pilots are well advised to personalize their performance at altitude.

Since symptoms of hypoxia can be different for each individual, the ability to recognize hypoxia can be greatly improved by experiencing and witnessing the effects of it during an altitude chamber "flight." The Federal Aviation Administration provides this opportunity under professional supervision at the Civil Aeromedical Institute in Oklahoma City, or at selected WINGS hypoxia demonstration events. To register and attend one of these courses, please visit the FAA's Airman Education Programs website.

Hyperventilation

Hyperventilation occurs when an individual is experiencing emotional stress, fright, or pain, and the breathing rate and depth increase, although the carbon dioxide level in the blood is already at a reduced level. The result is an excessive loss of carbon dioxide from the body, which can lead to unconsciousness due to the respiratory system's overriding mechanism to regain control of breathing

Pilots encountering an unexpected stressful situation may subconsciously increase their breathing rate. If flying at higher altitudes, either with or without oxygen, a pilot may have a tendency to breathe more rapidly than normal, which often leads to hyperventilation.

Since many of the symptoms of hyperventilation are similar to those of hypoxia, it is important to correctly diagnose and treat the proper condition. If using supplemental oxygen, check the equipment and flow rate to ensure the symptoms are not hypoxia related.

Common symptoms of hyperventilation include:

- Headache.
- Decreased reaction time.
- Impaired judgment.
- Euphoria.
- Visual impairment.
- Drowsiness.
- Lightheaded or dizzy sensation.
- Tingling in fingers and toes.
- Numbness.
- Pale, clammy appearance.
- Muscle spasms.

Hyperventilation may produce a pale, clammy appearance and muscle spasms compared to the cyanosis and limp muscles associated with hypoxia. The treatment for hyperventilation involves restoring the proper carbon dioxide level in the body. Breathing normally is both the best prevention and the best cure for hyperventilation. In addition to slowing the breathing rate, breathing into a paper bag or talking aloud helps to overcome hyperventilation. Recovery is usually rapid once the breathing rate is returned to normal.

Middle Ear & Sinus Problems

Ascents and descents can sometimes cause ear or sinus pain and a temporary reduction in the ability to hear. The physiological explanation for this discomfort is a difference between the pressure of the air outside the body and that of the air inside the middle ear and nasal sinuses.

The middle ear is a small cavity located in the bone of the skull. It is closed off from the external ear canal by the eardrum. Normally, pressure differences between the middle ear and the outside world are equalized by a tube leading from inside each ear to the back of the throat on each side, called the eustachian tube. These tubes are usually closed, but open during chewing, yawning, or swallowing to equalize pressure. Even a slight difference between external pressure and middle ear pressure can cause discomfort.

In a similar way, air pressure in the sinuses equalizes with the ambient or outside pressure through small openings that connect the sinuses to the nasal passages. An upper respiratory infection, such as a cold or sinusitis, or a nasal allergic condition can produce enough congestion around an opening to slow equalization. As the difference in pressure between the sinus and the ambient atmosphere increases, congestion may plug the opening. This "sinus block" occurs most frequently during descent. Slow descent rates can reduce the associated pain. A sinus block can occur in the frontal sinuses, located above each eyebrow, or in the maxillary sinuses, located in each upper cheek. It will usually produce excruciating pain over the sinus area. A maxillary sinus block can also make the upper teeth ache. Bloody mucus may discharge from the nasal passages.

Sinus block [*Figure 9-1*] can be avoided by not flying with an upper respiratory infection or nasal allergic condition. Adequate protection is usually not provided by decongestant sprays or drops to reduce congestion around the sinus openings. Oral decongestants have side effects that can impair pilot performance. If a sinus block does not clear shortly after landing, a physician should be consulted.

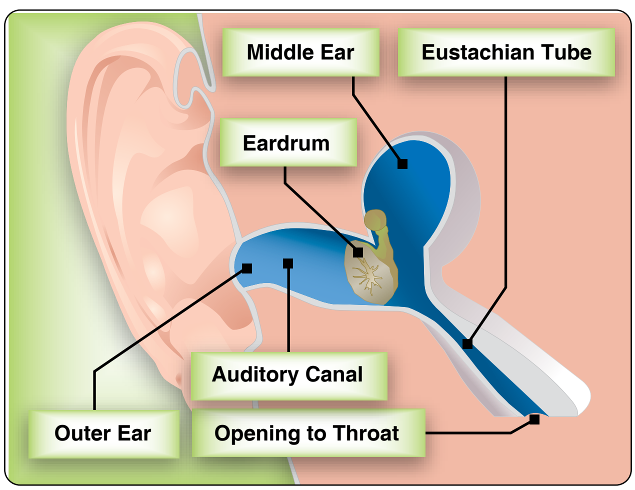

Figure 9-1. *The eustachian tube allows air pressure to equalize in the middle ear.*

During a climb, middle ear air pressure may exceed the pressure of the air in the external ear canal, causing the eardrum to bulge outward. Pilots become aware of this pressure change when they experience alternate sensations of "fullness" and "clearing." During descent, the reverse happens. While the pressure of the air in the external ear canal increases, the middle ear cavity, which equalized with the lower pressure at altitude, is at lower pressure than the external ear canal. This results in the higher outside pressure, causing the eardrum to bulge inward.

This condition can be more difficult to relieve due to the fact that the partial vacuum tends to constrict the walls of the Eustachian tube. To remedy this often painful condition, which also causes a temporary reduction in hearing sensitivity, pinch the nostrils shut, close the mouth and lips, and blow slowly and gently into the mouth and nose. This is commonly referred to as the Valsalva procedure.

The Valsalva procedure forces air through the eustachian tube into the middle ear. It may not be possible to equalize the pressure in the ears if a pilot has a cold, an ear infection, or sore throat. A flight in this condition can be extremely painful, as well as damaging to the eardrums. If a pilot experiences minor congestion, nose drops or nasal sprays may reduce the risk of a painful ear blockage.

Spatial Disorientation & Illusions

Balloon pilots rarely experience issues with spatial disorientation while in flight, as virtually all balloon operations are conducted under visual flight rules (VFR) conditions. Knowledge of these conditions, however, is important in the event of unusual circumstances or situations, such as inadvertently being caught in fog, or perhaps in areas of low visibility. The balloon pilot should have an awareness of these issues, so that appropriate actions may be taken as necessary.

Spatial disorientation specifically refers to the lack of orientation with regard to the position, attitude, or movement of an aircraft in space. The body uses three integrated systems working together to ascertain orientation and movement in space. The eye is by far the largest source of information. Kinesthesia refers to the sensation of position, movement, and tension perceived through the nerves, muscles, and tendons. The vestibular system is a very sensitive motion-sensing system located in the inner ears. It reports head position, orientation, and movement in three-dimensional space.

All this information comes together in the brain and, most of the time, the three streams of information agree, giving a clear idea of where and how the body is moving. Flying can sometimes cause these systems to supply conflicting information to the brain, which can lead to disorientation. During flight in visual meteorological conditions (VMC), the eyes are the major orientation source and usually prevail over false sensations from other sensory systems. When these visual cues are removed, as they are in instrument meteorological conditions (IMC), false sensations can cause a pilot to quickly become disoriented.

The vestibular system in the inner ear allows the pilot to sense movement and determine orientation in the surrounding environment. In both left and right inner ears, three semicircular canals are positioned at approximate right angles to each other. [*Figure 9-2*] Each canal is filled with fluid and has a section full of fine hairs. Acceleration of the inner ear in any direction causes the tiny hairs to deflect, which in turn stimulate nerve impulses, sending messages to the brain. The vestibular nerve transmits the impulses from the utricle, saccule, and semicircular canals to the brain to interpret motion.

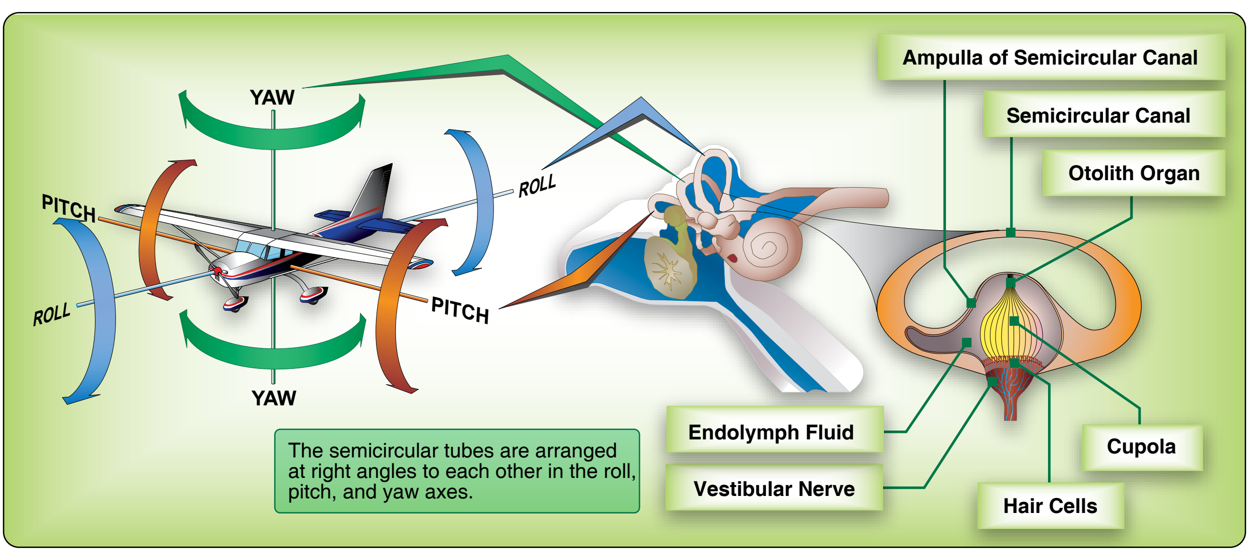

Figure 9-2. *The semicircular canals lie in three planes, and sense motions of roll, pitch, and yaw.*

The postural system sends signals from the skin, joints, and muscles to the brain that are interpreted in relation to the Earth's gravitational pull. These signals determine posture. Inputs from each movement update the body's position to the brain on a constant basis. "Seat of the pants" flying is largely dependent upon these signals. Used in conjunction with visual and vestibular clues, these sensations can be fairly reliable. However, the body cannot distinguish between acceleration forces due to gravity and those resulting from maneuvering the aircraft, which can lead to sensory illusions and false impressions of an aircraft's orientation and movement.

Again, under normal flight conditions, most balloon pilots and passengers do not experience spatial disorientation (or vertigo) while flying.

Motion Sickness

Under normal flight conditions, motion sickness is not an issue for most pilots or passengers. Motion sickness, or airsickness, is caused by the brain receiving conflicting messages about the state of the body. A pilot or passengers may experience motion sickness during initial flights, but it generally goes away within the first few flights. Anxiety and stress, which may be experienced at the beginning of flight training, can also contribute to motion sickness. Symptoms of motion sickness include general discomfort, nausea, dizziness, paleness, sweating, and vomiting.

Stress

Stress is defined as the body's response to physical and psychological demands placed upon it. The body's reaction to stress includes releasing chemical hormones (such as adrenaline) into the blood, and increasing metabolism to provide more energy to the muscles. Blood sugar, heart rate, respiration, blood pressure, and perspiration all increase. The term "stressor" is used to describe an element that causes an individual to experience stress. Examples of stressors include physical stress (noise or vibration), physiological stress (fatigue), and psychological stress (difficult work or personal situations).

Stress falls into two broad categories: acute (short term) and chronic (long term). Acute stress involves an immediate threat that is perceived as danger. This is the type of stress that triggers a "fight or flight" response in an individual, whether the threat is real or imagined. Normally, a healthy person can cope with acute stress and prevent stress overload. However, ongoing acute stress can develop into chronic stress.

Chronic stress can be defined as a level of stress that presents an intolerable burden, exceeds the ability of an individual to cope, and causes individual performance to fall sharply. Unrelenting psychological pressures, such as financial worries, difficult relationships, or work problems can produce a cumulative level of stress that exceeds a person's ability to cope with the situation. When stress reaches these levels, performance falls off rapidly. Pilots experiencing this level of stress are not safe and should not exercise their airman privileges. Pilots who suspect they are suffering from chronic stress should consult a physician.

Fatigue

Fatigue is frequently associated with pilot error. Some of the effects of fatigue include degradation of attention and concentration, impaired coordination, and decreased ability to communicate. These factors can seriously influence the ability to make effective decisions. Physical fatigue can result from sleep loss, exercise, or physical work. Factors such as stress and prolonged performance of cognitive work can result in mental fatigue.

Like stress, fatigue also falls into two broad categories: acute and chronic. Acute fatigue is short term and is a normal occurrence in everyday living. It is the kind of tiredness people feel after a period of strenuous effort, excitement, or lack of sleep. Rest after exertion and 8 hours of sound sleep ordinarily cures this condition.

A special type of acute fatigue is skill fatigue. This fatigue can be readily seen in the balloon pilot who, for example, has driven most or all of the night in order to attend an event, or perhaps was up for most of the previous night. [*Figure 9-3*]

Figure 9-3. *This pilot drove all night to make an event, but still will not be able to fly.*

This type of fatigue has two main effects on performance:

- Timing disruption—appearing to perform a task as usual, but the timing of each component is slightly off. This makes the pattern of the operation less smooth, because the pilot performs each component as though it were separate, instead of as a part of an integrated activity.
- Disruption of the perceptual field—concentrating attention upon movements or objects in the center of vision and neglecting those in the periphery. This may be accompanied by loss of accuracy and smoothness in control movements.

Acute fatigue has many causes, but the following are among the most important to the pilot:

- Mild hypoxia (oxygen deficiency).
- Physical stress.
- Psychological stress.
- Depletion of physical energy resulting from psychological stress.

Sustained psychological stress accelerates the glandular secretions that prepare the body for quick reactions during an emergency. These secretions make the circulatory and respiratory systems work harder, and the liver releases energy to provide the extra fuel needed for brain and muscle work. When this reserve energy supply is depleted, the body lapses into generalized and severe fatigue.

Acute fatigue can be prevented by proper diet and adequate rest and sleep. A well-balanced diet prevents the body from consuming its own tissues as an energy source. Adequate rest maintains the body's store of vital energy.

Chronic fatigue, extending over a long period of time, usually has psychological roots, although an underlying disease is sometimes responsible. Continuous high stress levels, for example, can produce chronic fatigue. Chronic fatigue is not relieved by proper diet and adequate rest and sleep, and usually requires treatment by a physician. An individual may experience this condition in the form of weakness, tiredness, palpitations of the heart, breathlessness, headaches, or irritability. Sometimes chronic fatigue even creates stomach or intestinal problems and generalized aches and pains throughout the body. When the condition becomes serious enough, it can lead to emotional illness.

If suffering from acute fatigue, stay on the ground. If fatigue occurs in the basket, no amount of training or experience can overcome the detrimental effects. Getting adequate rest and nutrition is the only way to prevent fatigue from occurring. Avoid flying without a full night's rest, after working excessive hours, or after an especially exhausting or stressful day. Pilots who suspect they are suffering from chronic fatigue should consult a physician.

Dehydration & Heatstroke

Dehydration is the term given to a critical loss of water from the body. The first noticeable effect of dehydration is fatigue, which in turn makes top physical and mental performance difficult, if not impossible. As a pilot, flying for long periods in hot summer temperatures or at high altitudes increases the susceptibility of dehydration since the dry air at altitude tends to increase the rate of water loss from the body. If this fluid is not replaced, fatigue progresses to dizziness, weakness, nausea, tingling of hands and feet, abdominal cramps, and extreme thirst. [*Figure 9-4*]

Figure 9-4. *Hydration is important both before and after participating in outdoor activities. While for obvious reasons during hot weather, an individual can dehydrate during cold weather, too.*

Heatstroke is a condition caused by inability of the body to control its temperature. Onset of this condition may be recognized by the symptoms of dehydration, but it has also been recognized only by complete collapse.

To prevent these symptoms, it is recommended that a pilot carry an ample supply of water to drink at frequent intervals on any long flight, whether thirsty or not.

Alcohol

Alcohol impairs the efficiency of the human body. Studies have proven that drinking and performance deterioration are closely linked. Pilots must make hundreds of decisions, some of them time critical, during the course of a flight. The safe outcome of any flight depends on the ability to make the correct decisions and take the appropriate actions during routine occurrences, as well as abnormal situations. The influence of alcohol drastically reduces the chances of completing a flight without incident. Even in small amounts, alcohol can impair judgment, decrease sense of responsibility, affect coordination, constrict visual field, diminish memory, reduce reasoning power, and lower attention span. As little as one ounce of alcohol can decrease the speed and strength of muscular reflexes, lessen the efficiency of eye movements while reading, and increase the frequency at which errors are committed. Impairments in vision and hearing can occur after consuming only one alcoholic drink.

The alcohol consumed in beer and mixed drinks is ethyl alcohol, a powerful central nervous system depressant. It acts on the body much like a general anesthetic. The “dose” is generally much lower and more slowly consumed in the case of alcohol, but the basic effects on the body are similar. Alcohol is easily and quickly absorbed by the digestive tract. The bloodstream absorbs about 80 to 90 percent of the alcohol in a drink within 30 minutes on an empty stomach. The body requires about 3 hours to rid itself of all the alcohol contained in one mixed drink or one beer.

When experiencing a hangover, a pilot is still under the influence of alcohol. Although a pilot may think that they are functioning normally, motor and mental response impairment is still present. Considerable amounts of alcohol can remain in the body for over 16 hours, so pilots should be cautious about flying too soon after drinking.

Altitude multiplies the effects of alcohol on the brain. When combined with altitude, the alcohol from two drinks may have the same effect as three or four drinks. Alcohol interferes with the brain’s ability to utilize oxygen, producing a form of histotoxic hypoxia. The effects are rapid because alcohol passes quickly into the bloodstream. In addition, the brain is a highly vascular organ that is immediately sensitive to changes in the blood’s composition. For a pilot, the lower oxygen availability at altitude and the lower capability of the brain to use the oxygen that is available can add up to a deadly combination.

Intoxication is determined by the amount of alcohol in the bloodstream. This is usually measured as a percentage by weight in the blood. 14 CFR part 91, section 91.17 requires that blood alcohol level be less than 0.04 percent and that 8 hours pass between drinking alcohol and piloting an aircraft. A pilot with a blood alcohol level of 0.04 percent or greater after 8 hours cannot fly until the blood alcohol falls below that amount. Even though blood alcohol may be well below 0.04 percent, a pilot cannot fly sooner than 8 hours after drinking alcohol. Although the regulations are quite specific, it is a good idea to be more conservative than the regulations.

Drugs

Pilot performance can be seriously degraded by both prescription and over-the-counter medications, as well as by the medical conditions for which they are taken. Many medications, such as tranquilizers, sedatives, strong pain relievers, and cough suppressants have primary effects that may impair judgment, memory, alertness, coordination, vision, and the ability to make calculations. Others, such as antihistamines, blood pressure drugs, muscle relaxants, and agents to control diarrhea and motion sickness have side effects that may impair the same critical functions. Any medication that depresses the nervous system, such as sedatives, tranquilizers, or antihistamines can make a pilot more susceptible to hypoxia.

Painkillers can be grouped into two broad categories: analgesics and anesthetics. Analgesics are drugs that reduce pain, while anesthetics are drugs that deaden pain or cause loss of consciousness.

Over-the-counter analgesics, such as acetylsalicylic acid (aspirin), acetaminophen (e.g., Tylenol), and ibuprofen (e.g., Advil) have few side effects when taken in the correct dosage. Although some people are allergic to certain analgesics or may suffer from stomach irritation, flying usually is not restricted when taking these drugs. However, flying is almost always precluded while using prescription analgesics, such as drugs containing propoxyphene (e.g., Darvon), oxycodone (e.g., Percodan), meperidine (e.g., Demerol), and codeine since these drugs may cause side effects such as mental confusion, dizziness, headaches, nausea, and vision problems. Anesthetic drugs are commonly used for dental and surgical procedures. Most local anesthetics used for minor dental and outpatient procedures wear off within a relatively short period of time. The anesthetic itself may not limit flying so much as the actual procedure and subsequent pain.

Stimulants are drugs that excite the central nervous system and produce an increase in alertness and activity. Amphetamines, caffeine, and nicotine are all forms of stimulants. Common uses of these drugs include appetite suppression, fatigue reduction, and mood elevation. Some of these drugs may cause a stimulant reaction, even though this reaction is not their primary function. In some cases, stimulants can produce anxiety and mood swings, both of which are dangerous when flying.

Depressants are drugs that reduce the body's functioning in many areas. These drugs lower blood pressure, reduce mental processing, and slow motor and reaction responses. There are several types of drugs that can cause a depressing effect on the body, including tranquilizers, motion sickness medication, some types of stomach medication, decongestants, and antihistamines. The most common depressant is alcohol.

Some drugs, which can be classified as neither stimulants nor depressants, have adverse effects on flying. For example, some forms of antibiotics can produce dangerous side effects, such as balance disorders, hearing loss, nausea, and vomiting. While many antibiotics are safe for use while flying, the infection requiring the antibiotic may prohibit flying. In addition, unless specifically prescribed by a physician, do not take more than one drug at a time, and never mix drugs with alcohol because the effects are often unpredictable.

The dangers of illegal drugs also are well documented. Certain illegal drugs can have hallucinatory effects that occur days or weeks after the drug is taken. Obviously, these drugs have no place in the aviation community.

14 CFR part 65 prohibits pilots from performing crewmember duties while using any medication that affects the body in any way contrary to safety. The safest rule is not to fly as a crewmember while taking any medication, unless approved to do so by the FAA. If there is any doubt regarding the effects of any medication, consult an AME before flying.

Scuba Diving

Scuba diving subjects the body to increased pressure, which allows more nitrogen to dissolve in body tissues and fluids. The reduction of atmospheric pressure that accompanies flying can produce physical problems for scuba divers. Reducing the pressure too quickly allows small bubbles of nitrogen to form inside the body as the gas comes out of solution. These bubbles can cause a painful and potentially incapacitating condition called the bends. (An example is dissolved gas forming bubbles as pressure decreases by slowly opening a transparent bottle of carbonated beverage.) Scuba training emphasizes how to prevent the bends when rising to the surface, but increased nitrogen concentrations can remain in tissue fluids for several hours after a diver leaves the water. The bends can be experienced from as low as 8,000 feet MSL, with increasing severity as altitude increases. As noted in the Aeronautical Information Manual (AIM), the minimum recommended time between scuba diving on non-decompression stop dives and flying is 12 hours, while the minimum time recommended between decompression stop diving and flying is 24 hours. [*Figure 9-5*]

Figure 9-5. *The reduction of atmospheric pressure that accompanies flying can produce physical problems for scuba divers.*

Vision in Flight

Of all the senses, vision is the most important for safe flight. Most of the things perceived while flying are visual or heavily supplemented by vision. As remarkable and vital as it is, vision is subject to some limitations, such as illusions and blind spots. The more a pilot understands about the eyes and how they function, the easier it is to use vision effectively and compensate for potential problems.

The eye functions much like a camera. Its structure includes an aperture, a lens, a mechanism for focusing, and a surface for registering images. Light enters through the cornea at the front of the eyeball, travels through the lens, and falls on the retina. The retina contains light sensitive cells that convert light energy into electrical impulses that travel through nerves to the brain. The brain interprets the electrical signals to form images. There are two kinds of light-sensitive cells in the eyes: rods and cones. [*Figure 9-6*]

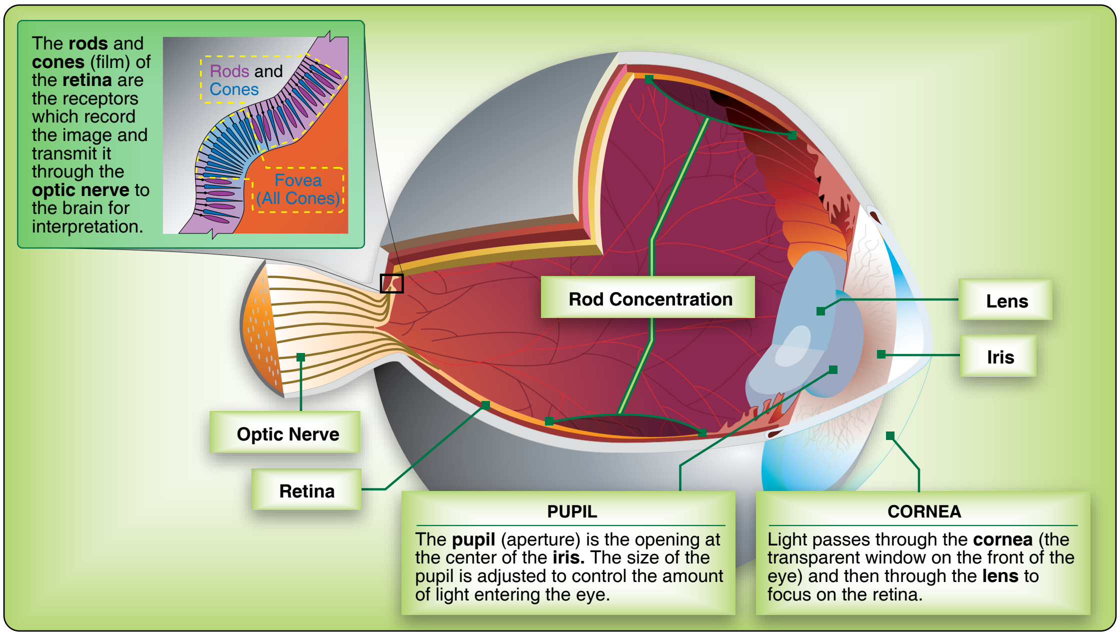

Figure 9-6. *The human eye.*

The cones are responsible for all color vision, from appreciating a glorious sunset to discerning the subtle shades in a fine painting. Cones are present throughout the retina, but are concentrated toward the center of the field of vision at the back of the retina. There is a small pit called the fovea where almost all the light sensing cells are cones. This is the area where most "looking" occurs (the center of the visual field where detail, color sensitivity, and resolution are highest).

While the cones and their associated nerves are well suited to detecting fine detail and color in high light levels, the rods are better able to detect movement and provide vision in dim light. The rods are unable to discern color but are very sensitive at low light levels. However, a large amount of light overwhelms the rods, and they take a long time to "reset" and adapt to the dark again. There are so many cones in the fovea that the very center of the visual field has virtually no rods at all. Therefore, the middle of the visual field is not very sensitive in low light. Farther from the fovea, the rods are more numerous and provide the major portion of night vision.

The area where the optic nerve enters the eyeball has no rods or cones, leaving a blind spot in the field of vision. Normally, each eye compensates for the other's blind spot. *Figure 9-7* provides a dramatic example of the eye's blind spot. Cover the right eye and hold this page at arm's length. Focus the left eye on the X in the right side of the windshield, and notice what happens to the balloon while slowly bringing the page closer to the eye.

Figure 9-7. *The eye's blind spot.*

Empty-Field Myopia

Another problem associated with flying at night or in reduced visibility is empty-field myopia, or induced nearsightedness. With nothing on which to focus, the eyes automatically focus on a point just slightly ahead of the aircraft. Searching out and focusing on distant light sources, no matter how dim, helps prevent the onset of empty-field myopia.

Night Vision

It is estimated that once fully adapted to darkness, the rods are 10,000 times more sensitive to light than the cones, making them the primary receptors for night vision. [*Figure 9-8*] Since the cones are concentrated near the fovea, the rods are also responsible for much of the peripheral vision. The concentration of cones in the fovea can create a night blind spot in the center of the field of vision. To see an object clearly at night, the pilot should expose the rods to the image. This can be done by looking 5° to 10° off center of the object to be seen. This can be tried in a dimly lighted room. When looking directly at the light, it dims or disappears altogether. When looking slightly off center, it becomes clearer and brighter.

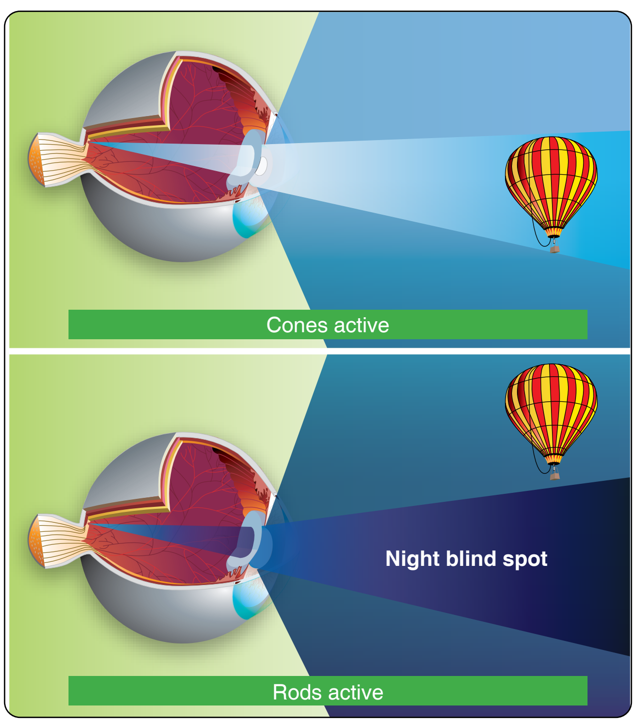

Figure 9-8. *Night blind spot*

When looking slightly off center, it becomes clearer and brighter. Refer to *Figure 9-8*. When looking directly at an object, the image is focused mainly on the fovea, where detail is best seen. At night, the ability to see an object in the center of the visual field is reduced as the cones lose much of their sensitivity and the rods become more sensitive. Looking off center can help compensate for this night blind spot. Along with the loss of acuity (sharpness) and color at night, depth perception and judgment of size may be lost.

Balloon pilots, while not normally conducting flight operations at night, can experience similar issues when flying in low light conditions, particularly if there is haze or reduced visibility. In those instances where the balloon is operated at night, such as during a night "glow" or tether, night vision can be immediately destroyed by the light from the burner. It may take several minutes for the pilot to recover their vision, time in which complete awareness of their surroundings is lost. If those surroundings include people, a potentially dangerous situation can ensue. Closing one eye during a burn and not looking at the burner flame will minimize this momentary blindness.

Diet and general physical health have an impact on how well a pilot can see in the dark. Deficiencies in vitamins A and C have been shown to reduce night visual acuity. Other factors, such as carbon monoxide poisoning, smoking, alcohol, certain drugs, and a lack of oxygen also can greatly decrease night vision.

Chapter Summary

Balloon pilots and glider pilots are unique in that they "self-certify" they are physically fit to conduct flight duties. This is an individual responsibility and must not be abused. The ability to "self-certify" becomes particularly problematic after the balloon pilot has had a major medical issue arise, such as a heart attack, angina, major surgery, and other items in this category. While they may be perfectly capable of piloting a balloon after triple bypass surgery, for example, it may not be the recommended course of action.

The best recommendation is to be aware of the provisions of 14 CFR part 67 and 14 CFR part 61, section 61.53. A balloon pilot who is not required to hold a medical certificate would still be well advised to consult with an AME or a physician who is familiar with aeromedical factors regarding medical issues which may be medically disqualifying and obtain recommendations on how best to proceed.