AEROSPACE PHYSIOLOGY

ARIZONA STATE UNIVERSITY

ALTITUDE CHAMBER

Human Factors in Flight

Introductory Course Manual

Revised: March 30, 2009

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Introduction

Welcome to Aerospace Physiology Training at Arizona State University Polytechnic. The enclosed reference material is designed to serve as a training aid and for your use outside of the classroom. The Mission of Aerospace Physiology is to acquaint you with the stresses of modern aviation. The aerospace environment exposes aircrew members to hostile environments, weather, temperature extremes, and changes in atmospheric pressure. Advancements in aeronautical and astronautical science increase the problems associated with these environments. Therefore, it is important that aircrew members know the characteristics of this environment and understand its effects on the human body.

In addition to the Physiological stresses, several other "Human Factors" are of concern in the flying environment. Physical, psychological, psychosocial, and pathological stresses are also examined and discussed in this course. Therefore, the study of Human Factors must consider the Physical, Physiological, Psychological, Psychosocial and Pathological limitations and capabilities as an individual interfaces with their environment. Although the course is aircrew oriented, the knowledge gained from this course may enable you to live a healthier and more rewarding life.

Symbols Used In This Course

0_2	Oxygen
N_2	Nitrogen
CO_2	Carbon Dioxide
CO	Carbon Monoxide
mm	Millimeters
Hg	Mercury
FL	Flight Level
M′ or K′	Thousand Feet
P____	Pressure of ____

Important Altitudes To Remember

50,000′	Maximum emergency altitude for pressure breathing. Pressure suit is required above this altitude.
43,000′	Safe operational altitude ceiling for pressure breathing. Full positive pressure breathing of 100% 0_2 equals breathing air at 10,000′.
40,000′	Above this altitude pressure breathing is necessary. Breathing 100% 0_2 at this altitude is equivalent to breathing air at 10,000′.
34,000′	Body requires 100% 0_2 to be equivalent to breathing air at sea level.
28,000′ to 32,000′	The Automatic Pressure Demand Regulator (MD 1) provides slight positive pressure (not PPB) to seal the mask and to insure that 100% 0_2 is delivered at 34,000 feet.
25,000′	Maximum altitude permitted for unpressurized flight.
18,000′	One-half of total atmospheric pressure (380 mm Hg).
10,000′	Supplemental Oxygen needed.

PHYSICS OF THE ATMOSPHERE

OBJECTIVES

1. Know the main component gases of atmosphere and their percentages.

2. Comprehend how atmospheric pressure and temperature change with altitude.

3. Know the characteristics of the physiological divisions of the atmosphere.

4. Comprehend the gas laws and their physiological significance.

I. Functions of the Atmosphere

A. Source of oxygen and carbon dioxide.

B. Shield against cosmic and solar radiation.

C. Protective layer that consumes meteors.

D. Source of rain.

E. Maintains the temperature and climate that sustains life.

II. Main Component Gases and Percentages

A. Oxygen (O_2) 21%, Nitrogen (N_2) 78% , Other Gases 1%.

1. Oxygen is biologically active.

2. Nitrogen is biologically inactive.

3. Gas percentages remain the same though the number of molecules decrease with altitude.

4. Gases are compressible, therefore pressure varies with altitude.

III. Atmospheric Pressure

A. The barometric (*atmospheric*) pressure is the combined weight of all the atmospheric gases creating a force upon the surface of the Earth. This force is caused by gravity pulling molecules earthward.

B. The weight (*pressure*) of a column of the atmosphere can be measured in pounds per square inch, in millimeters of mercury, or in inches of mercury.

C. Because gases are compressible, the effect of gravity on the gaseous atmosphere creates an envelope with the greatest density near the earth's surface.

D. As gas density decreases, the barometric pressure also decreases.

E. The amount of pressure which any gas contributes to the total pressure at any altitude is termed the "partial pressure" of that gas.

F. With a reduction in pressure on ascent, the pressure of each gas will decrease. This pressure change is greatest in the lower atmosphere where the gases are most compressed.

IV. Measurement of Altitude

A. True Altitude. The altitude of an object above mean sea level; as in using a tape measure to measure the height of the object. In fact, this altitude is measured by comparing the barometric pressure at altitude to the pressure at sea level. Therefore, local barometric pressure must be set into the altimeter to measure true altitude.

B. Absolute Altitude. The distance from the aircraft or space vehicle to the ground below it. This value change as terrain changes.

C. Pressure Altitude. An altitude referenced to 29.92 inches of Mercury (Hg). When the pressure is 29.92 inches of Hg (760 mmHg) and the temperature is +59°F (+15°C), a "standard day" is said to exist. Therefore, as barometric pressure changes occur locally, this altitude varies.

NOTE: Over the Continental United States, pressure altitudes are flown above 18,000 feet and are called "Flight Levels", i.e. FL180.

V. Physical Divisions of the Atmosphere

A. Troposphere

1. The layer of the earth's atmosphere closest to the surface of the earth. The troposphere extends from the earth's surface to approximately FL300 at the poles and FL600 at the equator.

2. This layer is characterized by changing weather, water vapor, and a constant rate decrease in temperature with an increase in altitude.

3. The tropospheric temperature lapse rate in a standard atmosphere is 2°C drop with each 1000-foot increase in altitude. This lapse rate continues up to the tropopause where the ambient temperature becomes a constant -55°C.

B. Tropopause

1. The tropopause is the interval of transition between the troposphere and the stratosphere. It varies in thickness from a few feet to several thousand feet.

2. The height of the tropopause is dependent upon latitude and season of the year. It is always farthest from the earth at the equator and nearest to the earth at the polar regions.

C. Stratosphere

1. The stratosphere is the layer above the troposphere that extends upward to an altitude of 50 miles.

2. It is characterized by an almost complete void of water vapor and turbulence and has a constant temperature of -55°C.

3. High velocity westerly winds called jet streams are present in the lower portion of the stratosphere.

D. Ionosphere

1. The ionosphere extends from 50 miles to an altitude of 600 miles.

2. In the ionosphere, charged particles of matter, ions, act as reflectors for electromagnetic energy or radio waves.

E. Exosphere

1. The exosphere extends from 600 miles to about 1200 miles.

2. The exosphere gradually becomes a vacuum of space.

VI. Physiological Divisions of the Atmosphere

A. Physiological Zone

1. Sea level to approximately 10,000 feet.

2. Zone to which the normal human body is adapted.

3. During ascent in this zone, atmospheric pressure drops from 760 mmHg to 523 mmHg.

4. Blood oxygen saturation drops from 98% to 87% and a certain degree of oxygen deficiency will occur.

5. Crewmembers are required to use supplemental oxygen above 10,000 feet.

6. The main problems imposed by ascent and descent in this zone are related to the middle ear and sinuses.

B. Physiologically Deficient Zone

1. Extends from approximately 10,000 feet to approximately FL500.

2. Because of a reduced atmospheric pressure, oxygen deficiency (hypoxia) is a major problem during ascent.

3. Trapped gas problems can occur in the intestinal tract and evolved gas problems can occur in the body tissues and joints.

4. Human survival depends upon pressurized cabins and oxygen equipment to deliver supplemental oxygen. The Physiologically Deficient Zone is also the zone where most high performance jet aircraft operate.

5. Pressure suits are required above FL500.

C. Space Equivalent Zone

1. Ranges from FL500 to 120 miles.

2. Problems of flight above FL500 are essentially the same as for space.

VII. The Gas Laws

A. Gas Expansion (*Boyle's Law*)

1. A volume of gas expands as the pressure surrounding it is reduced.

2. The physiological significance of this law is the problem of trapped gases within the body. It explains the effects of pressure changes on the ears, sinuses, hollow organs of the body, and gastrointestinal tract.

B. Gases in Solution (*Henry's Law*)

1. The amount of gas which is in solution in a liquid depends on the pressure of that gas around the solution. Scientifically stated, the amount of gas in solution is proportional to the partial pressure of that gas over the solution.

2. The physiological significance of this law is the problem of evolved gas in the body. The evolved gas disorder is also known as decompression sickness.

C. Gas Diffusion (*Law of Gaseous Diffusion*)

1. Gases diffuse or migrate from a region of high concentration (*or pressure*) to one of low concentration (*or pressure*) until an equilibrium is reached.

2. The physiological significance of this law is the gas exchange between man and his environment. It explains why oxygen moves into the blood, in the lungs, and from the blood into the tissues requiring oxygen for life.

D. Partial Pressure (*Dalton's Law*)

1. Each gas present in the atmosphere contributes to the total atmospheric pressure; thus, the sum of the partial pressures is equal to the total atmospheric pressure.

2. The physiological significance of this law is hypoxia. Although the percentage of oxygen in the air remains constant at all commonly used altitudes, its partial pressure will decrease in direct proportion to the total air pressure.

E. Charles's Law

1. The pressure of a gas is directly proportional to its temperature (*volume remaining constant*).

2. This law has little direct physiological significance since body temperature remains fairly constant. It explains that pressure within an oxygen cylinder will decrease if the temperature of the cylinder decreases, even when no oxygen has been used from it.

RESPIRATION/CIRCULATION

OBJECTIVES

1. Comprehend the functions and definition of respiration.
2. Comprehend the mechanism of breathing.
3. Know the process of gas exchange and transportation.
4. Comprehend the circulatory system's primary function.

I. Definition:

Respiration/Circulation is the process in which a living organism exchanges gases with its environment.

II. Functions of the Respiratory System

A. Intake of oxygen (0_2).

B. Removal of carbon dioxide.

C. Maintenance of body heat balance.

D. Maintenance of acid-base balance of the body.

III. Metabolism

A. Sum of chemical and physical processes which maintain life.

B. Fuel + 0_2 = ENERGY + $C0_2$ + H_2O.

IV. Anatomy of the Respiratory Tree

A. The Oral-Nasal Cavities.

B. The Trachea.

C. The Lungs.

D. Alveoli.

V. Mechanics of Respiration

A. Inhalation: active, requires muscular effort.

B. Exhalation: passive, muscles relax.

VI. Phases of Respiration (See Fig. 2-1)

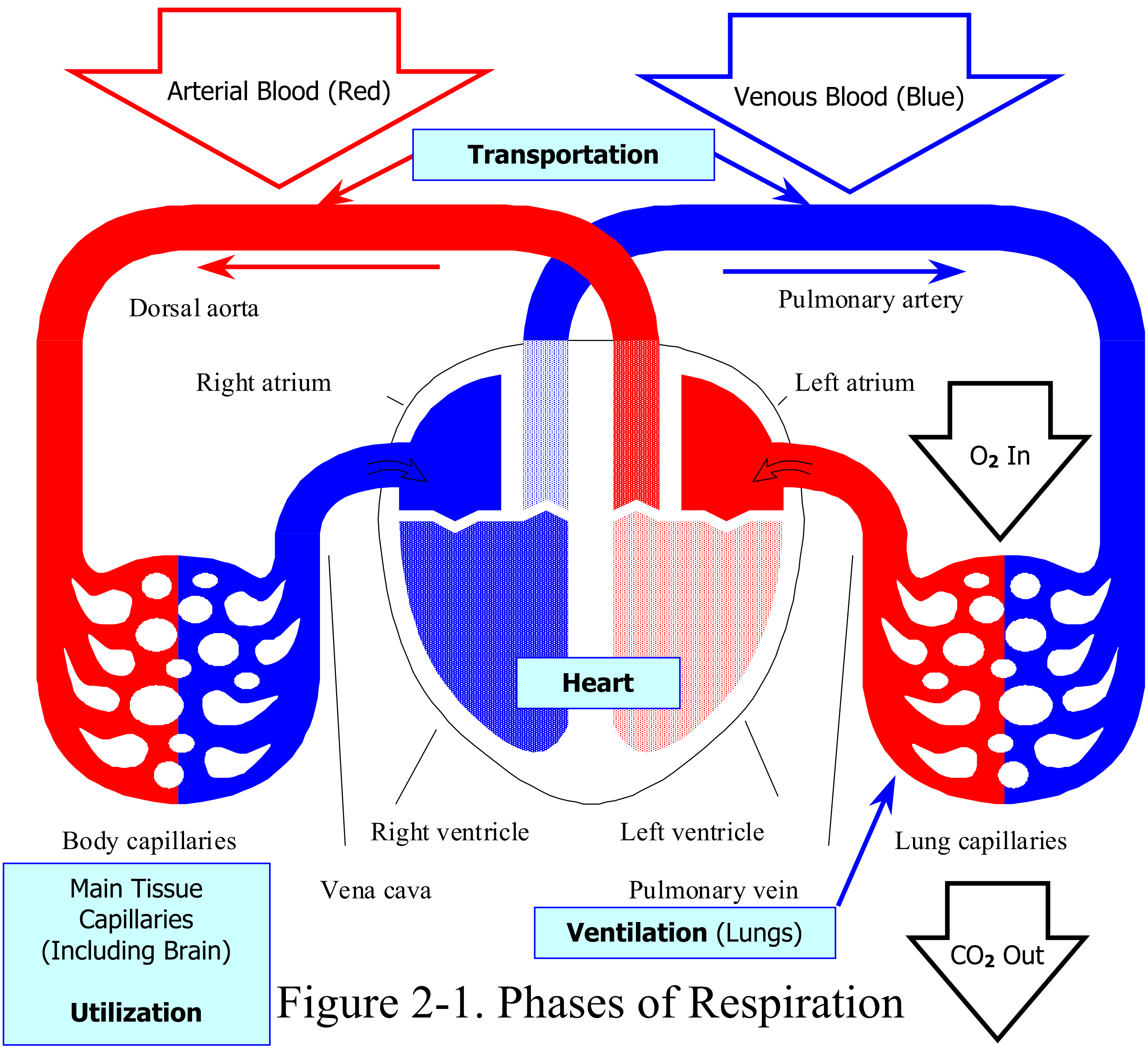


Figure 2-1. Phases of Respiration

A. Ventilation

1. The exchange of gases between the blood and the environment.

2. Regulated to provide adequate delivery of oxygen and removal of carbon dioxide to satisfy the demands of metabolism.

B. Transportation

1. The blood circulation which connects the external gaseous environment with the individual cells of the body.

Figure 2-1. Phases of Respiration

2. Any factor which alters the blood flow or ability of the blood to carry oxygen and carbon dioxide will disturb metabolism.

C. Utilization

1. The participation of oxygen energy-releasing reactions, with the production of the waste product - carbon dioxide.

2. Also known as metabolism or cellular respiration, this function will be affected by changes in the ventilation or transportation phases.

D. Diffusion

1. Serves as an interface between the ventilation-transportation and between the transportation-utilization phases.

2. Represents the diffusion of gases across cell membranes in the lungs as well as in the tissues.

VII. Control and Regulation of Breathing:

A. Chemical Control

1. Respiratory Center

a. Located in pons and upper portion of the medulla.

b. Sensitive to the level of carbon dioxide in the blood, $C0_2$ is the primary control of respiration.

c. One function of respiration, related to acidity level, is the maintenance of balance between $C0_2$ and other blood constituents. Too much $C0_2$ in the blood makes it acidic and too little makes it alkaline. The amount of $C0_2$ in the blood is constantly monitored by parts of the respiratory center in the brain.

d. The oxygen concentration appears to have little or no direct effect upon the respiratory center.

2. Chemoreceptors

a. Groups of sensing cells found in the circulatory system.

b. Responsive to changes in the partial pressures of oxygen and carbon dioxide of the arterial blood.

c. Secondary stimulus to the adjustment of respiration.

B. Nervous Control (Involuntary)

1. Emotional stresses such as fear and anxiety.

2. May override normal chemical control.

C. Voluntary

VIII. Functions of Circulation

A. Transports nutrients and oxygen to body tissues.

B. Removes waste products from tissues.

C. Maintains constant body temperature.

D. Regulates acid-base balance.

E. Protects against infection.

F. Maintains water and electrolyte balance.

G. Transports hormones.

IX. The Blood

A. *Definition:* A flowing, circulating tissue found in all higher animals, including humans. It contains living cells and has specific functions, the most important of which is the conveyance of materials from one part of the body to another.

B. Composition of the Blood

1. Red Blood Cells (RBC's).

   a. Transport oxygen and carbon dioxide.

   b. Hemoglobin, a protein, is responsible for 0_2 transport.

2. White Blood Cells (WBC's).

3. Platelets.

4. Plasma.

X. The Heart

A. Anatomy

1. Chambers.

   a. Atria.

   b. Ventricles.

2. Valves.

B. Cardiac Cycle

XI. The Vascular System

A. Arteries: Muscular, elastic tubes which carry blood away from the heart under high pressure to the tissues.

B. Veins: Thin-walled, low pressure, non-elastic vessels which carry oxygen-poor blood from the tissues to the heart.

C. Capillaries: The smallest of all the vessels are a vital part of the circulatory system because it is through them that the actual transfer of dissolved gases and solids -- outward and inward -- are made.

XII. Physiology of Circulation (See Fig. 2-2)

A. Mechanics

B. Control

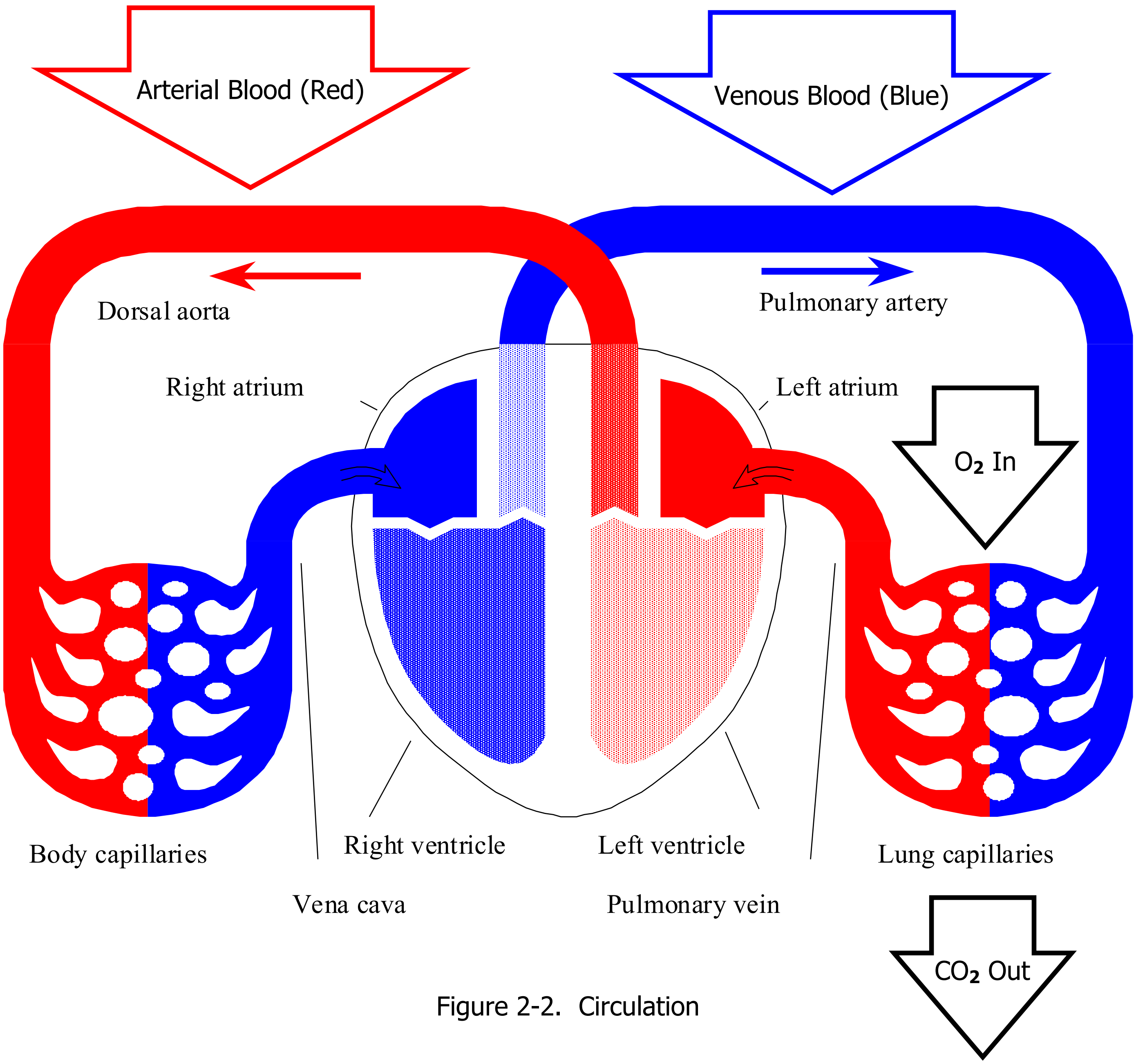


Figure 2-2. Circulation

HYPOXIA/HYPERVENTILATION

OBJECTIVES

1. Know the four types of hypoxia and their causes.

2. Know five individual symptoms of hypoxia.

3. Comprehend the characteristics of hypoxia that will influence the onset of symptoms in the flying environment.

4. Know the corrective steps used by crewmembers in the treatment of hypoxia.

5. Know the causes of hyperventilation.

6. Know the symptoms of hyperventilation.

7. Know the symptoms that can be used to differentiate between hypoxia and hyperventilation.

8. Know the corrective steps to be taken by crewmembers in the treatment of hyperventilation.

I. Definition: Hypoxia is a state of oxygen deficiency in the blood, cells, and tissues sufficient to cause impairment of function.

II. Types

A. Hypoxic Hypoxia: "Altitude Hypoxia" due to reduction of 0_2 pressure in the lungs.

1. Improper or malfunctioning 0_2 equipment, avoidable through PRICE check.

2. Loss of cabin pressurization.

3. Not using supplemental 0_2 above 10,000' (cabin altitude).

4. Drowning.

5. Pneumonia.

B. Hypemic Hypoxia: Blood's inability to accept sufficient 0_2.

1. Carbon monoxide.
2. Anemia.
3. Blood loss or donation.
4. Sulfa drugs.

C. Stagnant Hypoxia: Blood pooling causing insufficient flow of oxygenated blood to brain and tissues.

1. G-forces.
2. Shock.
3. Temperature extremes.
4. Positive pressure breathing.
5. Prolonged sitting or bed rest.
6. Hyperventilation.

D. Histotoxic Hypoxia: Inability of tissue cells to accept and utilize 0_2.

1. Alcohol.
2. Narcotics and other drugs.
3. Cyanide and other poisons.

III. General Characteristics of Hypoxia

A. All hypoxias are additive.

B. All hypoxias are insidious - give little warning.

C. All hypoxias cause intellectual impairment.

IV. Hypoxia Symptoms

A. Subjective Symptoms (felt by you)

1. Apprehension.
2. Blurred or tunnel vision.
3. Dizziness.
4. Fatigue.
5. Headache.
6. Hot and Cold Flashes.
7. Nausea.
8. Numbness.
9. Tingling.
10. Euphoria.
11. Belligerence.

B. Objective signs (seen by others)

1. Increased breathing.
2. Cyanosis.
3. Poor judgment.
4. Loss of muscle coordination.
5. Mental confusion.
6. Unconsciousness.

V. Time of Useful Consciousness (TUC) (See Table 3-1)

A. Interval of time from interruption of an adequate oxygen supply to loss of the ability to help yourself.

B. A rapid decompression can reduce the TUC as much 50% because of the forced exhalation from the lungs.

Table 3-1: Times of Useful Consciousness at Various Altitudes

FL500 and above	9 - 12	seconds
FL430	9 - 12	seconds
FL400	15 - 20	seconds
FL350	30 - 60	seconds
FL300	1 - 2	minutes
FL280	2 - 3	minutes
FL250	3 - 5	minutes
FL220	10	minutes
FL180	20 - 30	minutes

VI. Factors Influencing Hypoxia

A. Altitude.

B. Rate of ascent.

C. Duration of exposure.

D. Rate of decompression.

E. Individual tolerance.

F. Physical fitness.

G. Physical activity.

H. Environmental temperatures.

I. Self-imposed stress.

VII. Prevention of Hypoxia

A. Cabin pressurization (primary method used).

B. Use of oxygen equipment (in case of cabin pressurization loss, insures oxygen pressure in lungs is still adequate).

VIII. Treatment of Hypoxia:

A. Supply lever - ON.

B. Diluter lever - 100% "GANG LOAD"

C. Pressure lever - EMERGENCY.

D. Check connections (includes "putting the mask on").

E. Control the rate and depth of breathing.

F. Descend below 10,000 feet and land ASAP.

IX. Definition*:* Hyperventilation is a condition in which the rate and depth of respiration is abnormally increased.

A. This contributes to an abnormal reduction of $C0_2$ in the blood and lungs, resulting in a disturbance of the acid-base balance of the blood, a condition known as respiratory alkalosis.

B. In severe cases, usually associated with injury or disease, excessive acid-base deviations may stop body functions and cause death.

C. In a healthy crewmember, hyperventilation can cause a decrease in performance and unconsciousness.

X. Causes of Hyperventilation

A. Voluntary: One can voluntarily alter the ventilation rate. Therefore, hyperventilation can be voluntarily induced or corrected by merely increasing or decreasing the rate and depth of breathing.

B. Emotional: The human psyche can also override the normal respiratory controls. Fear, anxiety, stress, or tension, resulting from emotional or physical discomforts, will sometimes cause an individual to unconsciously override the normal control of breathing. This is the most frequent cause encountered during initial chamber flights.

C. Pain: Can also predispose a crewmember to overbreathe by causing fear and apprehension.

D. Hypoxia: With the onset of hypoxia, oxygen tension in the blood is reduced below minimum acceptable levels. This creates a reflex impulse to the respiratory center via the chemoreceptors which increases the rate and depth of breathing. As this is continued, more $C0_2$ is eliminated and the blood becomes more alkaline. As a result, hyperventilation may be a complicating factor when hypoxic hypoxia is encountered.

XI. Symptoms of Hyperventilation

A. Mild or moderate hyperventilation

1. Dizziness, fatigue, headache, nausea, hot and cold flashes, tingling.

2. Virtually identical to hypoxia (cyanosis with hypoxia only).

B. Severe hyperventilation

1. Muscle tightening (tetany) - does not occur with hypoxia.

2. Loss of consciousness.

XII. Treatment of Hyperventilation: Identical to the treatment of hypoxia because the symptoms between the two are nearly identical. You do not have time to determine which one you have.

A. Supply lever - ON.

B. Diluter lever - 100% "GANG LOAD"

C. Pressure lever - EMERGENCY.

D. Check connections (includes "putting the mask on").

E. Control the rate and depth of breathing.

F. Descend below 10,000 feet and land ASAP.

XIII. Pressure Breathing

A. Pressure breathing is a method of maintaining adequate alveolar $p0_2$ at high cabin altitudes.

B. Positive pressure breathing causes a reversal of the breathing cycle. The normal phenomena of active inspiration and passive expiration must be charged to a passive inspiration and a very active expiration.

C. Pressure breathing may also cause hyperventilation because there is a tendency to overbreathe when the breathing cycle is reversed.

D. Control of the rate and depth of breathing when pressure breathing can prevent hyperventilation.

E. Pressure breathing has some limitations. When used at high altitudes for extended periods of time, the increased pressure in the lungs reduces the return of blood to the heart and may result in stagnant hypoxia. This effect on the circulatory system is the greatest limiting factor in pressure breathing.

TRAPPED GAS PROBLEMS

OBJECTIVES

1. Know the areas of the body where trapped gases may be a problem.

2. Know the procedures for prevention and relieving problems of trapped gases.

3. Comprehend the appropriate treatment for each area of trapped gas.

I. Mechanical Effects of Changes in Barometric Pressure

A. The body can withstand enormous changes in total barometric pressure, as long as air pressure in body cavities is equalized with the ambient pressure.

B. The gastrointestinal tract, middle ears, paranasal sinuses and respiratory tract are the body structures that normally contain gas.

C. These gases are influenced by pressure changes occurring outside the body. When the pressure is decreased on ascent to altitude, the gases expand; on descending from altitude, the gases will contract. This mechanical response to decreased and increased pressures is in accordance with Boyle's Law.

II. Areas of Trapped Gas Problems

A. The Middle Ear (See Fig. 4-1)

1. Effects due to changing barometric pressure.

a. Ascent to Altitude

i. As barometric pressure is reduced during ascent, expanding air in the middle ear finds intermittent release through the eustachian tube.

ii. As pressure in the middle ear increases, the eardrum bulges outward until a differential pressure is reached and a small amount of air is forced out the eustachian tube, and the eardrum resumes its normal position.

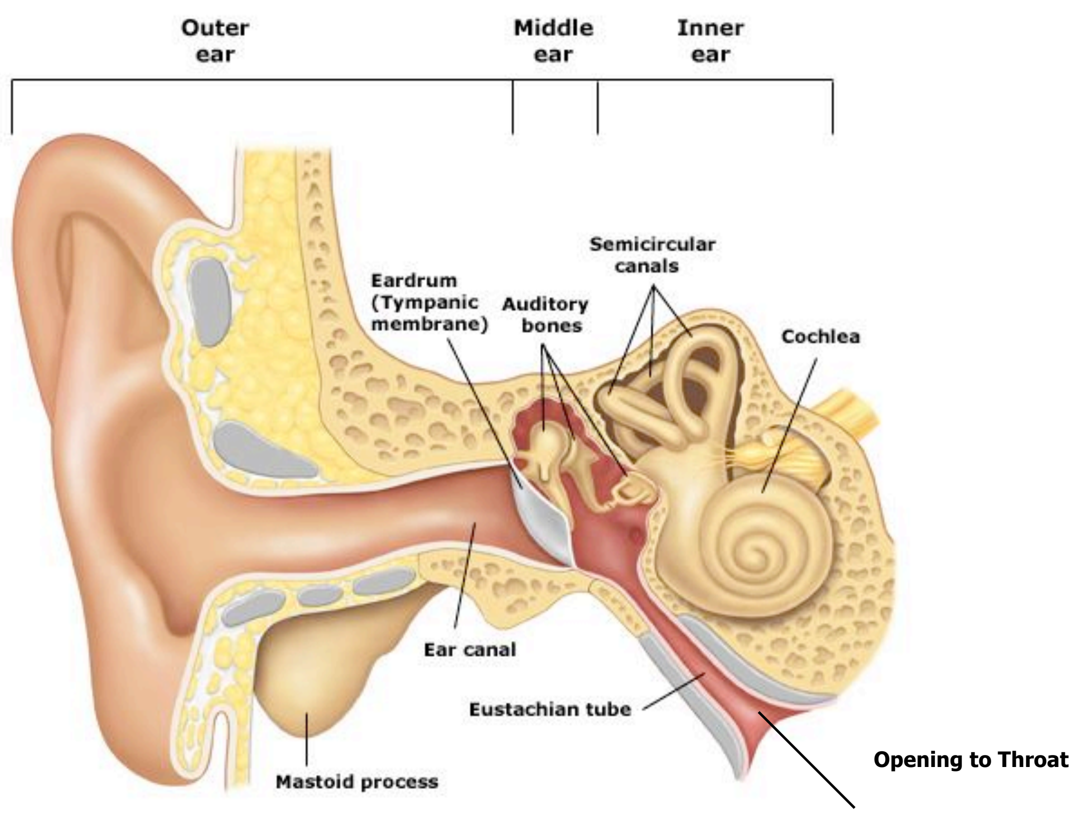
b. Descent from Altitude

i. During descent, equalization of pressure in the ear does not occur automatically.

ii. The eustachian tube acts as a flutter valve allowing air to pass outward easily, but resists its passage in the opposite direction.

iii. During descent, the pressure of the ambient air rises above that inside the middle ear and the eardrum is forced inward.

iv. If the pressure differential is allowed to increase to an appreciable extent, it may be difficult to open the eustachian tube.



2. Ear Block

a. Characteristics

i. When equalization of pressure in the ears cannot be accomplished during changes in barometric pressure, a condition occurs called barotitis media (ear block).
ii. There is seldom difficulty clearing the ears on ascent, and usually no difficulty in equalizing pressure during descent. However, due to the action of the eustachian tube, the majority of ear blocks occur on descent.

iii. The "ear block" is characterized by middle ear congestion.

iv. Inflammation, discomfort, and pain is usually followed by temporary impairment of hearing. This occurs when the eustachian tube opening is restricted as the result of inflammation or infection from a head cold, sore throat, infection of the middle ear, sinusitis, or tonsillitis.

b. Treatment

i. The <u>Valsalva Maneuver</u> may be performed to force air through the previously closed eustachian tube into the middle ear, thereby equalizing the pressure differential between the middle ear and the atmosphere. This maneuver is performed by pinching the nose shut and attempting to exhale through the nose.

ii. If ear pain and a resulting block occur during descent, relief may be obtained by ascending to a level at which equalization of the pressure can be accomplished. (During a chamber flight, this is often times referred to as "bouncing the chamber.")

iii. Nasal sprays are sometimes effective in relieving an ear block.

iv. Ear blocks occurring during an altitude chamber flight can also be treated by use of the politzer bag. The politzer bag is used to force air through the eustachian tube to the middle ear. The result is equalization of pressure between the middle and outer ear.

NOTE: If a descent continues without an equalization of pressure across the eardrum, the pain becomes intense and the eardrum may perforate. If the eardrum is ruptured, hearing is usually restored in a short time if the eardrum is kept clean and protected from infection. Usually, there is no impairment of hearing.

c. Prevention

i. The best method of preventing an ear block is to not fly with a cold.

ii. Whenever exposed to pressure charges. whether in an altitude chamber or in the actual flying environment, always remember to keep the pressure between the middle and outer ears equalized. This is referred to as "staying ahead of the ears" and is very important on descent. This may be accomplished by swallowing, yawning, moving the lower jaws, or tensing the muscles in the throat.

iii. The Valsalva Maneuver is generally very effective in the equalization of pressure during descents.

iv. It should be mentioned that the self-medication of colds is not a preventative measure against ear blocks or, for that matter, sinus blocks.For example, individuals who fly as crewmembers in the military must never "self-medicate;" rather, they must always consult a flight surgeon. All the dangers of using over-the-counter drugs are to numerous to mention, but the use of so-called "nasal sprays" poses a special problem. Such nasal sprays exert their positive effects by constricting the fluid carrying vessels around nasal and sinus tissues. This "vasoconstriction" reduces swelling of tissue and permits the free flow of air into and out of the middle ear and sinus cavities. The relief lasts about 12 hours or less, but afterwards the tissue fluid is restored to the "fluid-starved" tissue, and sometimes additional use of "vasoconstrictor nasal spray" may not be able to relieve swelling as before; this problem is referred to as the "rebound effect." The worst circumstance which can happen for a self-medicator is to be able to get to altitude but not be able to get down. Severe ear blocks or sinus blocks may result. Occasionally military flight surgeons will dispense such nasal sprays to persons to carry after the worst of a cold has passed to be used in an emergency as a "get you down" alternative (It is recommended that all aircrew members carry a vasoconstrictor with them during the flight in the event an emergency arises.) Because of the rebound effect, it is unwise to ever use the nasal sprays preemptively or before flying to prevent trouble. Rather, use the vasoconstrictor only in an emergency!!!

3. Delayed Ear Block

   a. Often crewmembers who have been breathing 100% oxygen at altitude or in an altitude chamber develop ear distress two to six hours after descent, particularly if 0_2 breathing was maintained during descent to ground level.

   b. This results from the 0_2 in the middle ear being absorbed, thereby creating a decreased pressure in the middle ear.

   c. Crewmembers should accomplish a Valsalva Maneuver several times after aircraft or altitude chamber flight, and several times before going to bed to compensate for 0_2 absorption from the middle ear.

B. The Sinuses (See Fig. 4-2)

1. Characteristics of the sinuses and sinus problems

   a. The sinuses most often involved with pressure changes are the frontal sinuses located above each eyebrow, and the maxillary sinuses located in the bone of the cheek on either side of the nose.

   b. The sinus ducts have openings into the nasal passages on either side. With pressure changes occurring upon ascent or descent, the gas within the sinuses increases or decreases in volume in the same manner as the gas in the middle ear.

   c. Normally, the gas is vented to the outside upon ascent with no discomfort.

   d. Upon descent, air moves through the duct back into the sinuses. If the sinus ducts are open, there is no discomfort; however, if the openings of the sinus ducts are malformed or swollen due to an Upper Respiratory Infection (URI), there may be a tendency for a blockage of the ducts to occur.

e. Sometimes upon ascent, a blockage will occur at the opening of the duct within the sinus. This will prevent the expanding gas from venting to the outside and, as the pressure builds up within the sinus, localized discomfort will occur.

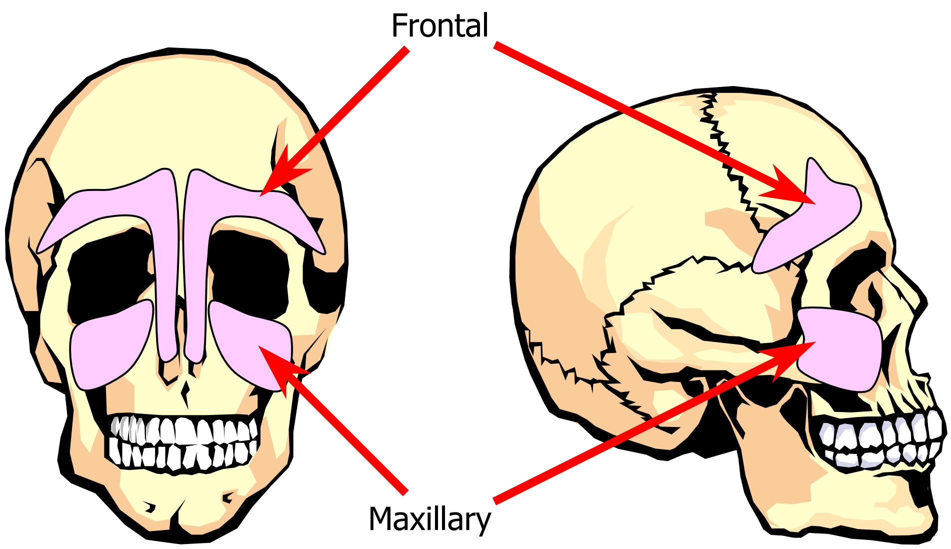


Figure 4-2. Location of the Sinuses

2. Treatment

a. Pain can, and most frequently does, occur upon descent. To prevent excessive pain, the pressure must be equalized as rapidly as possible.

b. The Valsalva Maneuver is sometimes effective in clearing sinus blocks.

c. Coughing against pressure (*supplied by a regulator*) may also be effective in the treatment of sinus blocks.

d. If pain is too great, the direction of pressure change must be reversed as rapidly as possible. In flight, the altitude is changed as required; this will usually relieve the condition. When the condition is corrected, slower rates of changes in pressure will usually prevent recurrence.

e. Nasal sprays are sometimes effective in relieving sinus blocks.

f. In some cases of sinus blockage, the crewmember may have bloody mucous discharge from the nasal passages, which should not be alarming.

g. Frequently, with blockage of the ducts leading into the maxillary sinuses, it is difficult for individual to differentiate the pain. The pain may be referred to the upper teeth and can be mistaken for barodontalgia.

3. Prevention

a. The best method of preventing a sinus block is to not fly with a cold.

b. Whenever exposed to pressure changes, whether in an altitude chamber or in the actual flying environment, keep the pressure between the sinuses and the outside equalized.

c. The Valsalva Maneuver is generally very effective in the equalization of pressure during descents.

C. The Gastrointestinal Tract

1. Characteristics

a. The symptoms most frequently experienced with a rapid decrease in atmospheric pressure is discomfort from the expansion of gas within the gastrointestinal tract.

b. Above FL250, enough distention may occur to produce severe pain and unconsciousness.

c. The chief sources of the gas are swallowed air and food undergoing digestion.

d. At high altitudes, there may be interference with breathing due to the gas expansion.

2. Treatment

a. As gases in the stomach and intestine expand with altitude, extreme discomfort may result unless relief is obtained by belching or passing of flatus.

b. Expulsion of gas is frequently aided by walking or moving about. When walking or moving is not possible, massaging the affected area from right to left and down, will often times aid in the expulsion of gas.

c. If gas expulsion cannot be accomplished and pain is severe, it will be necessary to descend to a higher pressure to prevent incapacitation or shock.

3. Prevention

a. Though gas-forming foods may have direct influence on the production of abdominal gas and symptoms at high altitudes in certain individuals, it is more likely that specific types of food alter the sensitivity of the intestinal tract to gaseous distention.

b. Crewmembers who participate in high altitude flights or altitude chamber flights should remember to avoid foods that they know disagree with them (*gas-producing foods*).

c. Anxiety and/or nervousness are associated with the increased production of gastric acid in the stomach. Associated with this increase in the gastric acid production is an increase in the amount of gas. In other words, controlling one's anxiety and nervousness before flights will help keep excess gas production to a minimum.

d. Eating regularly and maintaining proper elimination are also important in preventing excess gas production.

e. Eating irregularly, hastily, or while working makes the individual more susceptible to gas pain.

D. The Teeth

1. Characteristics

a. The incidence of tooth pain or barodontalgia is low but, when it occurs, it is usually an excruciating pain.

b. The altitude at which the onset of tooth pain usually occurs varies. The pain may, or may not, become more severe as altitude increases.

c. Research reveals that changes in barometric pressure do not cause dental disease. However, some conditions that do not cause discomfort at ground level may be adversely affected, and become exaggerated and painful with barometric changes. Almost without exception, confirmed barodontalgia is experienced only in previously restored or defective teeth.

d. Untreated caries, or cavities, especially those under old restorations, and those in which the pulp has become exposed, may be the cause of tooth pain at altitude.

e. A less frequent cause of tooth pain during ascent is the presence of a root abscess which creates a small amount of gas. This trapped gas may expand and cause severe pain which can be relieved only by descent.

2. Treatment and Prevention

a. The only way to treat persistent tooth pain while in an altitude chamber or in the actual flying environment is to descend as soon as possible. Descent invariably brings relief; the pain often disappears at the same altitude at which it was first observed.

b. Good dental hygiene is the most practical way to prevent tooth problems at altitude.

EVOLVED GAS DISORDERS

(*Decompression Sickness*)

OBJECTIVES

1. Know the four types of evolved gas sickness, the body area effected by each, and the specific symptoms of each type.

2. Know the proper steps to take should an evolved gas problem occur in the actual flying environment.

3. Comprehend the primary means of preventing decompression sickness in the actual flying environment.

I. Definition: Evolved gas disorders are defined as the effects produced by the evolution of gas from tissues and fluids of the body.

A. Henry's Law: The amount of gas that will dissolve in a solution and remain in solution is directly related to the pressure of that gas over the solution.

B. When the atmospheric pressure is decreased rapidly to certain critical values, the pressure gradient between body gas pressure (*nitrogen*) and the outside air is such that the dissolved body nitrogen will come out of solution in the form of bubbles. This can occur in the blood, other body fluids, and body tissues.

C. The ascent rates of modern aircraft are great enough to establish such conditions. An altitude of FL250 has been considered by some sources to be the critical altitude. However, there are documented cases of crewmembers reporting decompression sickness at altitudes as low as 18,000 feet (*Haldane's 1/2 an atmosphere*).

II. Variable Factors in Decompression Sickness

A. Rate of Ascent: The more rapid the rate of ascent, the sooner the symptoms appear.

B. Altitude: At altitudes lower than FL250, the incidence is low. Above FL250, symptoms may occur after leveling off at cruising altitude.

C. Duration of Exposure: Incidence and severity depend upon the length of flight at high altitudes.

D. Physical Activity: Exercise lowers the altitude or time threshold for all manifestations of decompression sickness, particularly the bends.

E. Age: Occurrence of symptoms increases with age.

F. Body Fat: Bends pain is more severe and the likelihood of an individual encountering severe decompression sickness is greater as the proportion of body fat is increased.

G. Individual Susceptibility: The reaction of most individuals is unpredictable for a given flight.

H. Cabin Pressurization: Pressurization systems are designed to keep the body at an altitude below FL250.

I. Scuba Diving: Diving with SCUBA will greatly lower the threshold altitude for the occurrence of decompression sickness. Cases of decompression sickness have occurred in individuals exposed to commercial aircraft cabin altitudes of 5000 to 8000 feet when the flight occurred within the previous 3-hour to 6-hour period following the SCUBA diving event.

(*Note for Reference: United States Air Force regulations require a 24-hour delay between diving and flying*.)

III. Types of Decompression Sickness

A. The Bends

1. Generally somewhat localized in and around the joints of the body. The larger joints such as the shoulders, elbows, knees, and ankles are the usual sites.

2. Factors such as exercise, time at altitude, and increased altitude have a bearing on the degree of pain.

3. In severe cases of the bends, it becomes unbearable to move the affected joint. (*It is strongly recommended to immobilize the affected area*.)

4. A mission could very definitely be compromised because of the bends.

5. Descent below the altitude at which it occurred will usually decrease the pain or it will disappear.

6. Re-ascent to the same altitude will cause the pain to return, and it will usually be in the same location.

B. Chokes

1. This condition is rare, but potentially very dangerous.

2. Sometimes develops at higher altitudes and indicates that bubbles exist in the smaller blood vessels in the lungs.

3. There is a deep and sharp pain centrally located under the sternum; a dry, progressive, nonproductive cough develops; and the ability to take a normal breath decreases.

4. Expansion of the lungs causes the pain to become worse, and there is a sense of suffocation and apprehension.

5. Symptoms of shock may appear.

C. False Chokes (*Not a form of decompression sickness*.)

1. Condition caused by mouth-breathing and cool, dry aircraft oxygen.

2. Sometimes results in throat irritation and discomfort.

3. The throat irritation is usually relieved following fluid intake.

D. Skin Manifestations (*Paresthesia*)

1. Mild type of decompression sickness involving peculiar sensations of the skin, which may include a mottled and diffuse rash.

2. Believed to be caused by very small bubbles of gas evolving under the skin.

3. Bubbles produce stimuli to the many different kinds of subcutaneous nerve receptors causing sensations which include itching, hot or cold feelings, and tingling.

4. It is possible that the very small bubbles may produce interference with the blood flow in and around the nerve endings, and this may produce irritation.

5. Skin symptoms in themselves are usually not serious; however, they should be taken as a warning signal that the environmental situation is such that bubbles may be coming out of solution.

6. Continued exposure may lead to more serious types of decompression sickness.

E. Neurological Manifestations (*CNS*)

1. In rare cases, on exposure to high altitudes, symptoms indicate the brain (*and less frequently, the spinal cord*) may be affected by bubbles.

2. The more common symptoms are disturbances of vision, which may vary from blind spots in the visual field to flushing or flickering vision (*scotomata*).

3. There may be a dull-to-severe persistent headache, partial paralysis, disturbances in sensation, inability to speak or hear, and loss of orientation.

4. Unilateral paresthesia, or one-sided numbness and tingling in one arm, leg, or side may also occur.

5. The current opinion is that the bubbles circulate through the vessels resulting in many small areas of localized hypoxia.

6. The symptoms are unpredictable.

IV. Prevention from Decompression Sickness

A. Denitrogenation: Breathing 100% oxygen for a period of time before exposure to low barometric pressure.

1. Very effective in eliminating a great amount of N_2 from the body except in very obese individuals.

2. When 100% 0_2 is breathed by means of a mask or other appropriate 0_2 equipment, no atmospheric N_2 enters the lungs. This eliminates the lung N_2 pressure. N_2 then rapidly diffuses from the tissues to the blood, then to the lungs and is exhaled.

B. Cabin Pressurization: The primary means of preventing decompression sickness in the actual flying environment is cabin pressurization. A low earth-like environment (*cabin altitude less than 10,000 feet*) is maintained.Otherwise, using supplemental 0_2, flights are restricted to cabin altitudes below FL250.

V. Treatment of Decompression Sickness

A. Descend immediately or as soon as possible. Declare an emergency!

B. All crewmembers: Place oxygen to 100% immediately. Use emergency pressure if necessary. (*This step will help remove excess N_2 from the body tissues*.)

NOTE: Immobilize the affected area if possible.

C. Landing will be accomplished at the nearest suitable installation where medical assistance can be obtained.

NOTE: Report to the flight surgeon or best-qualified medical assistant. Before the individual may continue flight, he or she must have a consultation with a flight surgeon, flight medical officer, or civilian aeromedical examiner (*AME*).

D. Compression (*Hyperbaric*) Chamber Therapy (*if necessary*)

NOTE: Contact Nearest Hyperbaric Medicine facility.

NOTE: If you are treated for decompression sickness and no neurological deficit remains, you will be returned to "flying status".

VISION

OBJECTIVES

1. Know the visual characteristics of rod and cone vision.
2. Comprehend the limitations of vision, and know the methods of ensuring 20/20 visual acuity during day and night flying.
3. Know the definition and the method of minimizing autokinesis.

I. Introduction

A. Of all our sensory systems, the eyes are the most important for flying.

B. Air traffic control, radar, and similar techniques are incapable of ensuring aircraft separation. It is important to realize that the "see and avoid" concept is the only reliable method of maintaining aircraft separation, and avoiding midair collision".

C. The crewmember needs good depth perception for safe landings, good visual acuity for signaling other aircraft and targets, good color vision for identifying signal flares and beacons, and good night vision for night operations.

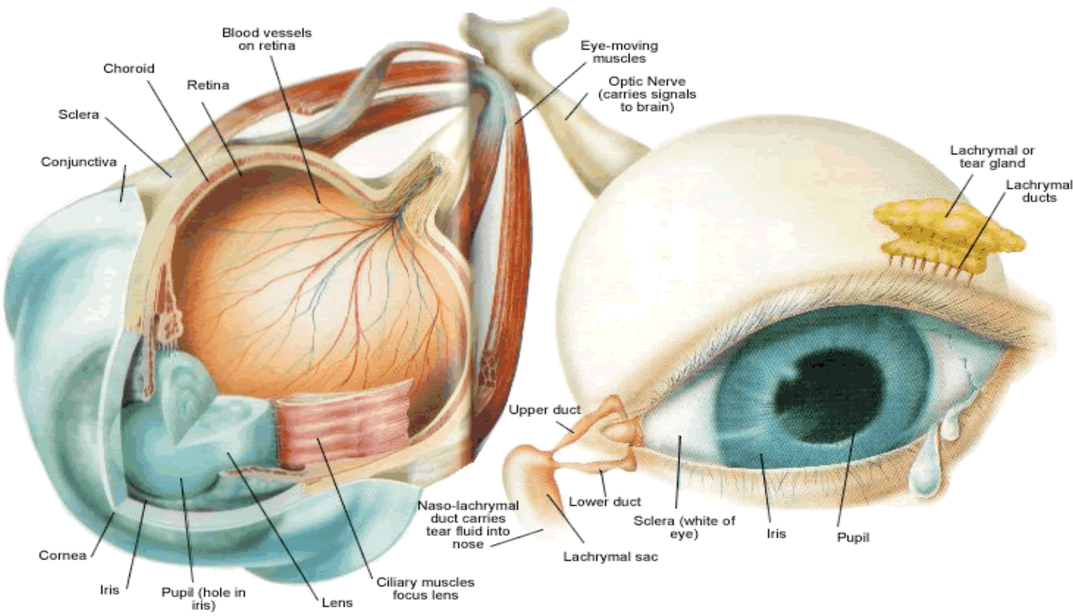
D. A crewmember possessing average visual acuity capacity who knows the rules for better vision has a greater advantage than one with superior vision, but who does not know how to "see."

II. Anatomy of the Eye (See Fig. 14-1)

A. Structures

1. Cornea.
2. Iris.
3. Pupil.
4. Lens.
5. Retina.
6. Rods and cones.
7. Optic nerve.

Fig. 6-l: The Eye



B. The Visual Blind Spot (See Fig. 6-2 and 6-3)

1. The site at which the optic nerve enters the eye, the optic disc, is devoid of either rods or cones, creating a blind spot in the visual field of that eye.
2. The combining of the nerve impulses from both eyes in the brain successfully avoids a visual blind spot.
3. However, if vision to one eye is obstructed, an image falling on the optic disc of the other eye will not be perceived. This is due to the lack of rods or cones at the optic disc where the optic nerve enters the eye.
4. The field of the blind spot widens as distance from the eye increases

Fig. 6-2: Visual Blind Spot

For this image, close your right eye. With your left eye, look at the red circle. Slowly move your head closer to the image. At a certain distance, the blue line will not look broken!! This is because your brain is "filling in" the missing information.

Don't Stare

We're all a little bit blind. That's right, you may pass eye tests without a blink, have 20/20 vision, even see in the dark but you could still miss seeing a jumbo Jet at a mile and a half if the conditions are right. There's a blind spot in your eye about 30 degrees right of center when you're looking straight ahead. Your peripheral vision from the eye compensate for this "defect" because your brain normally combines the pictures from both eyes.
When the peripheral vision from one eye is obstructed, the brain can't fill in the missing part of the picture. That's really not a problem when you're walking around on the ground. But when you get inside of a racing machine, American flying machine, etc-and look outside, things start getting in the way, like passengers, copilots, or windscreen posts.

Fig. 6-3

"Big deal," you say," All I have to do is move my head," Maybe so, but try this test. Hold the picture below at arms length and focus both eyes on the cross on the left windscreen, Now, move the picture toward your face, you should be able to see the airplane all the way in. Okay? Try it again with your left eye closed. The airplane will disappear and then reappear as you draw the picture closer.
Ask yourself: how much airspace will my aircraft cover during the time the other airplane disappeared?

C. Functions of Rods and Cones**.**

1. The cone cells are used for day (high-intensity light) vision and color vision.
2. The rods are used for night (low-intensity light) vision.

3. An area in the center of the retina, the fovea, contains a high concentration of cone cells, but no rod cells; the concentration of rods increases toward the periphery of the retina.
4. Each cone cell in the fovea is connected to individual nerve fibers leading to the brain. This means that under sufficient light conditions, each cone cell will generate an individual nerve impulse to the brain.
5. Conversely, many rod cells are connected to a single nerve fiber;' the additive effect of very dim light stimulating a few rods may cause a nerve impulse to be generated.
6. The periphery of the retina, where the rods are concentrated, is about 10,000 times as sensitive to light as is the fovea.

D. Types of Vision

1. Cone Vision
    a. Cone cells are used when there is a lot of light present, during daylight hours.
    b. Cone cells allow us to see in color.
    c. The area of concentrated cone cells called the fovea offers more visual acuity than other areas of cone cells because there are many more individual nerve connections there.
    d. When you want to look at something closely you will have to move your eyes so that the image falls on the fovea.
    e. The most effective way to use your eyes during day flight is to use central vision in a series of fixations (scanning).
2. Rod Vision
    a. Rod cells are located along the outer edges of the retina and provide us with our ability to see at night.
    b. The photosensitive chemical found in the rod cells is 1,000 to 10,000 times more sensitive to light than the chemical of cone cells.
    c. Although rod cells are very sensitive to light, they do not provide accurate vision, and they offer no color vision, only varying shades of gray.

d. At night in the dark, the fovea area with all of its many cone cells becomes a "blind spot" because if you look at an object as you would during the daylight hours, it will fall on the fovea which has no night vision rod cells, and therefore, you will not see the object. A crewmember must locate objects by using "off-center" vision, and keep the objects in view by continuous small movements of the eyes.

E. Factors Affecting Vision at High Levels of illumination

1. Visibility and Reflective Surfaces

a. Reflection on glass surfaces results in a loss of transmitted light since the total light striking the surface is either transmitted, absorbed, or reflected.

b. When only one surface is involved, as with windshields or sunglasses, this loss is too small to be an important factor.

c. However, the reflection may be a source of trouble. The reflective glare of a canopy in sunlight may reveal the position of an aircraft before the aircraft can actually be seen.

d. Instrument reflections on the canopy may be extremely annoying or distracting to the crewmember.

e. Diminished contrast results from scratching or fogging of transparent materials, as each scratch or water droplet becomes a source of scattered light.

f. To provide the best possible visibility, windscreens and other transparent viewing surfaces should be kept clean and scratch-free.

g. If the glass or transparent plastic through which a crewmember looks distorts the pattern of light rays, which forms the retinal image, visibility is impaired. There are two principal sources of distortion: lenses of sunglasses or visors, and transparent panels used in the aircraft.

2. Space Myopia or Empty Field Vision

a. At high altitudes or during extended over water flights, crewmembers may develop physiological adjustment of the eye due to a lack of distant objects on which to fixate. This is known as accommodation.

b. A varying degree of nearsightedness develops. For example, a crewmember with normal visual acuity of 20/20 is able to discern an aircraft having a fuselage diameter of 7 feet at a distance to 4.5

miles. When accommodated to relative nearsightedness, the crewmember would not be able to detect the same aircraft at a distance greater than 3 miles.

F. Factors Affecting Vision at Low Levels of Illumination

1. Dark Adaptation

a. The eyes adapt slowly to darkness when passing from a lighted area to a darkened one.

b. This process is called dark adaptation, and is caused by progressive regeneration of photosensitive substances in the cones and rods.

c. The rods contain a substance called rhodopsin, or visual purple, which bleaches very rapidly when exposed to bright light, but is regenerated slowly during a 3O-minute period of dark adaptation.

d. The sensitivity to dim light acquired by staying in darkness for 30 minutes can be lost by turning on a bright light for as little as 5 seconds.

2 .Adverse Sunlight Exposure

a. Experiments disclose that exposures to bright sunlight have a cumulative and adverse effect on dark adaptation.

b. Crewmembers exposed to intense sunlight for 3 to 5 hours show a definite decrease in sensitivity at low levels of illumination; this persists for as long as 5 hours after exposure,

3. Artificial Aids

a. Apparently, many believe that with increased usage of electronic devices for navigation, aircraft identification, and target detection of high performance aircraft, the importance of red cockpit lighting has diminished. Don't you believe it!

b. Some dark adaptation prior to flight can also be achieved by wearing red-lens goggles, but this method is not routinely used.

c. Although red light is most desirable for preservation of dark adaptation, its use results in disturbance of normal color relationships. Under red light, color differences are lost, and brightness values are greatly distorted.

d. Objects that are normally red will appear very light, whereas green and blue objects will appear dark.

4. Loss of Color Perception

   a. Perception of color is not possible with the rods.

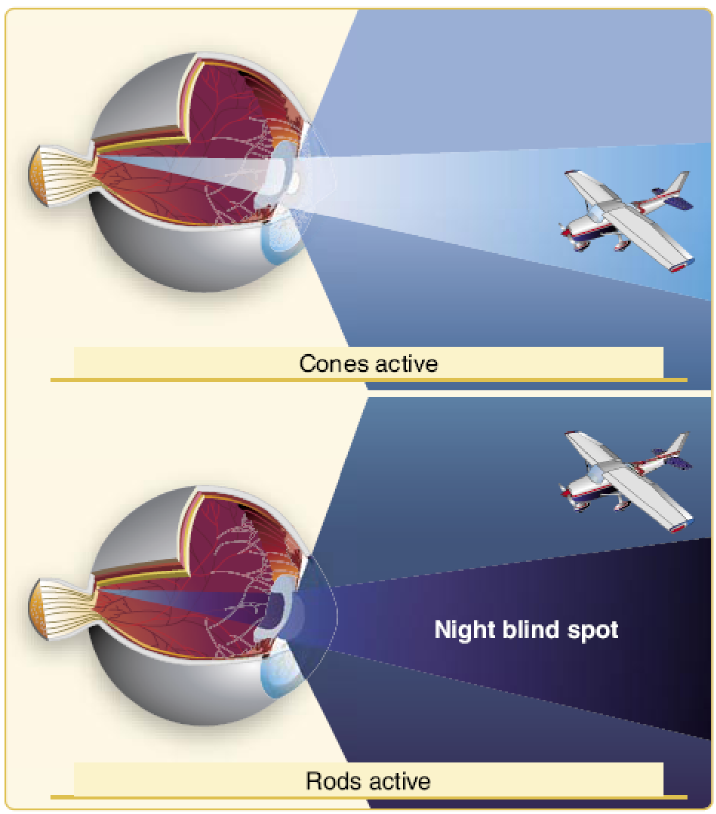
   b. It is only possible to distinguish between the light and dark colors at night only in terms of the intensity of reflected light.

5. The Night Visual Blind Spot (See Fig. 14-3)

   a. To perceive an object in dim light, the image must not fall on the fovea blind spot.

   b. A crewmember must locate objects by using off-center vision, and keep the objects in view by continuous small movements of the eye.

Fig. 6-3: The Night Visual Blind Spot



6. Loss of Acuity

   a. Perception of fine detail is impossible- at night.

b. Reduced visual acuity at night results from the numerous rods connected to single nerve fibers in the peripheral retina. The fovea cones are individually connected to nerve fibers, giving greater visual acuity under daylight conditions.
c. Because visual acuity at night is so poor, the size of objects becomes extremely important. At night, an unlighted aircraft can be seen from about 1,000 feet only if off-center vision is used!

7. Visibility at Night
   a. The crewmember's ability to see through the windscreen is easily impaired at night.
   b. Contrast between an object and its background at night may be further reduced by reflections of cockpit lights from the interior surface of the windscreen.
   c. Transparent panels must be kept clean, and interior lights must be turned off or dimmed to minimum levels.
8. Individual Variation
   a. There is considerable dim light visual acuity variation among crewmembers.
   b. Practicing off-center vision in dim light may increase the ability and efficiency of night vision.

G. Effects of Altitude on Night Vision

1. Exposure to reduced oxygen tensions at high altitudes causes an increase in the time required for dark adaptation, and a decrease in ability to see at night.
2. At 10,000 feet, without supplemental oxygen, night vision is about 75% as effective as at sea level. For this reason, crewmembers should use supplemental oxygen on night flights from ground level to altitude.

Carbon Monoxide and Night Vision

1. Hypoxia resulting from carbon monoxide poisoning affects visual acuity, brightness, discrimination, and dark adaptation identically to hypoxia resulting from reduced oxygen partial pressures.
2. As little as 5% carboxyhemoglobin saturation will affect the visual threshold and elevate the physiological altitude.

3. Smoking three cigarettes in rapid succession may cause a temporary 10% carboxyhemoglobin saturation with an effect on visual sensitivity equal to an altitude of 8,000 feet without supplemental oxygen.

H. Effects of Diet on Night Vision

1. Vitamin A and possibly Vitamins B and C are chemical factors essential to good night vision.
2. Foods containing Vitamin A are eggs, butter, cheese, liver, apricots, peaches, vegetables, and cod liver oil.

I. Techniques of Seeing

1. Scanning
    a. The sky must be continually scanned so that successive areas are focused on or near the fovea area of the retina.
    b. In scanning, maximum effectiveness is achieved by a series of short regularly shaped eye movements.
    c. The specific pattern of scanning movements must conform to the requirements of each crew position and must compensate for the movement of the aircraft.
    d. Scanning areas must be established for specific aircrew positions in each type of aircraft so that no area of the sky is unsearched.
2. Depth Perception
    a. An opinion of distance is usually derived on a subconscious level without the crewmember be aware of the evidence on which he bases his decision.
    b. Clues to distance or depth perception are monocular and depend upon the relative sizes of objects, their shadows, individual movements, and their movements relative to one another.
    c. Takeoff and landing, formation flying, and air-to-air refueling require good depth perception.
3. Visual Problems of High-Speed Flight
    a. The time delay associated with visual perception is an important problem in high-speed flight.
    b. Time lags related to visual perception, decision-making, and physical reaction are unacceptable in supersonic aircraft, and necessitate special

instrumentation such as radar to identify objects in time to take evasive action.

c. Good scanning habits should be developed to avoid collisions during both day and night flying operations.

J. Two-Mode Visual System

1. Focal Mode

a. Used for tasks requiring acuity or resolution.

b. Exclusively visual.

c. Requires good lighting and good optical resolution.

d. Requires conscious attention.

e. Confined to the optical center of the eye.

f. Actively focuses on objects for recognition and detail.

2. Ambient Mode

a. Orients us to the "ambient" environment.

b. Tells us where we are and whether we, or the environment, are moving.

c. Includes the entire retina of the eye.

d. Functions quite well at low light levels.

e. Does not require acuity correction.

f. Passively takes in the "quality" of the surroundings.

g. Functions at a reflex level, rather than a conscious level.

h. Acts in connection with the other senses to subserve spatial orientation, balance, posture, and gaze stability.

K. Visual Illusions

1. Glare Effects

a. When the eyes are dark-adapted, sudden exposure to bright light will cause a rapid loss of sensitivity.

b. A significant proportion of image loss will occur before the eyelids can be closed; full adaptation to the new light takes several seconds.

c. The eyes act independently with respect to individual light adaptation. If a light should occur during night conditions, closing one eye will preserve the major part of its dark adaptation while the dark adaptation of the open eye might be lost. The practical importance is obvious.

d. If possible, both eyes should be closed to avoid loss of retinal sensitivity; if vision is demanded while the glare persists, one eye should remain closed.

2. Auto kinetic Movement

   a. Staring at a fixed light in the dark produces the illusion that the light is moving erratically (autokinetic phenomenon).

   b. Example- If a crewmember is attempting a formation join-up at night, and stares fixedly at an ignited afterburner ahead, loss of aircraft control or a midair collision may result while trying to follow the apparent movement of the afterburner.

   c. Although the exact cause of autokinesis is unknown, it may be prevented or dispelled by continually shifting eye fixations from point to *point* and observing other lights in the visual field.

L. Flash blindness

1. Lightning, camera flash bulbs, explosives, and sudden bright lights can cause flash blindness.
2. The flash from a nuclear explosion can be intense enough to permanently "cook" the retina; therefore, many forms of eye protection have been developed including eye patches, window curtains, bi-density glasses, and recently, goggles with shutter-like closures which respond to the flash by immediately reducing the size of the light hole until the intensity of the light is no longer as dangerous. These shutter-like glasses are called "PUT Goggles."

M. Suggestions for Improved Vision

1. Practice and develop effective "scanning" and "off-center" vision techniques.
2. Avoid self-imposed stress.
3. Avoid glare prior to flying at night.
4. Include Vitamin A in your diet.
5. Allow sufficient time for dark adaptation to occur.
6. Avoid bright light during night operation.
7. Ensure clean windows and canopies.

NOTE: The Air Force has done considerable research on "'contrast sensitivity" (the ability to separate an object from its background). It appears that good vision not only requires good acuity, but also good sensitivity to contrast. Contrast sensitivity testing may one day compliment the Snellen test in visual examinations by providing a basis for predicting job performance and success in the flying environment.