FM 3-04.301(1-301)

AEROMEDICAL TRAINING FOR FLIGHT PERSONNEL

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HEADQUARTERS, DEPARTMENT OF THE ARMY

Preface

Lessons learned from previous military conflicts and recent contingency operations have caused changes in Army aviation doctrine and the development of more sophisticated aircraft and weapons systems. Army aircrew members must be capable of operating these systems around the clock, in austere environments, and under adverse conditions. They must be capable of employing these systems and avoid enemy air defense and air-to-air weapons systems. The hazards of stress and fatigue imposed by operating more sophisticated systems in combat operations and CONOPS will eventually take a toll in aircrew performance and could jeopardize mission accomplishment. Aircrew members must be trained to recognize and understand these hazards. Training can prepare aircrew members and prevent stress and fatigue from reducing their mission effectiveness and increase their chances of survival.

This manual gives aircrew members an understanding of their physiological responses to the aviation environment; it also describes the effects of the flight environment on individual mission accomplishment. In addition, it outlines the essential aeromedical training requirements (in Chapter 1) that assist the commander and flight surgeon in conducting aeromedical education for Army aircrew members. The subject areas addressed in the training are by no means all inclusive but are presented to assist aircrew members in increasing their performance and efficiency through knowing human limitations. This manual is intended for use by all Army aircrew members in meeting requirements set forth in AR 95-1, TC 1-210, and other appropriate aircrew training manuals.

The proponent of this publication is Headquarters, TRADOC. Send comments and recommendations on DA Form 2028 (Recommended Changes to Publications and Blank Forms) to Dean, US Army School of Aviation Medicine, ATTN: MCCS-HA, Fort Rucker, Alabama 36362-5377.

The provisions of this publication are the subject of the following international agreement: STANAG 3114 (Edition Six).

The use of trade names in this manual is for clarity only and does not constitute endorsement by the Department of Defense.

This publication has been reviewed for operations security considerations.

Unless this publication states otherwise, masculine nouns or pronouns do not refer exclusively to men.

Field Manual
No. 3-04.301(1-301)

Headquarters
Department of the Army
Washington, DC, 29 September 2000

Aeromedical Training for Flight Personnel

Contents

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Chapter 1

Training Programs

Aircrews must be trained and ready in peacetime to perform their missions in combat or other contingency operations. Therefore, leaders at all levels must understand, sustain, and enforce high standards of combat readiness. Tough, realistic training should be designed to challenge and develop soldiers, leaders, and units. This chapter outlines the essential aeromedical training requirements needed for all aircrew members.

TRAINING REQUIREMENTS

1-1. All U.S. Army flight students receive aeromedical training during initial flight training and during designated courses given at the United States Army Aviation Center, Fort Rucker, Alabama. Aeromedical training is also provided for specific aviators during refresher training courses. In addition, unit commanders are responsible for aeromedical training at the unit level.

AEROMEDICAL TRAINING IN SPECIFIC COURSES

1-2. Initial aeromedical training is conducted for all U.S. Army students in the Initial Entry Rotary Wing Course. Their initial physiological training is performed according to the provisions of STANAG 3114 and TRADOC programs of instruction at USAAVNC. Aeromedical training is conducted for aviators receiving transition or advanced training at USAAVNC in the following courses:

- Fixed-Wing Multiengine Qualification Course.
- Fixed-Wing Multiengine Instructor Pilot Course.
- Aviation Safety Officer Course.

HYPOBARIC REFRESHER TRAINING

1-3. Crew members and Department of the Army civilians who fly in pressurized aircraft or in aircraft that routinely exceed 10,000 feet MSL receive hypobaric training. Refresher training is conducted once every three years. The aviators trained are those who fly in pressurized aircraft or in aircraft that routinely exceed 10,000 feet MSL.

1-4. Refresher training consists of classroom instruction to review the essential materials presented in the initial training. After completing classroom instruction, aviators participate in a hypobaric (low-pressure/high-altitude) chamber exercise using the appropriate profile for the aircraft flown (see the appendix).

SPECIAL TRAINING BY OTHER SERVICES

1-5. U.S. Air Force or U.S. Navy physiological training units can be used if aviators cannot attend aeromedical training, including hypobaric (low-pressure/high-altitude) chamber qualification, at the U.S. Army School of Aviation Medicine at Fort Rucker. Initial and refresher training conducted by the other services normally meets U.S. Army requirements or can usually be modified to meet the needs of U.S. Army units. The physiological training conducted by other services meets U.S. Army requirements for renewing aeromedical training currency for a three-year period.

UNIT TRAINING

1-6. The unit commander must develop an aeromedical training program that meets the unit's specific needs as part of the Aircrew Training Program governed by TC 1-210. This training is crucial because most Army aircrew members are not required to attend the established refresher training courses previously described.

1-7. The unit's mission and its wide range of operations are the important factors for commanders to consider in developing an aeromedical training program. The program includes the various aeromedical factors that affect crew members' performance in different environments, during flight maneuvers, and while wearing protective gear. The unit aeromedical training program will contain, as a minimum, the continuous training and special training described below.

1-8. Because of the medical and technical nature of the aeromedical training program, commanders will involve their supporting flight surgeon in developing the program. The flight surgeon will provide input into all aspects of unit aviation plans, operations, and training. Commanders can obtain further assistance in developing a unit aeromedical training program from the Dean, US Army School of Aviation Medicine, ATTN: MCCS-HA, Fort Rucker, Alabama 36362-5377.

CONTINUOUS TRAINING

1-9. The requirement for continuous training applies to all U.S. Army aircrew members in operational flying positions. The POI must be conducted in intervals of three years or less. When personnel turnover is high, a two-year cycle is recommended. The following subjects are the minimum training necessary for the unit to obtain adequate safety and efficiency in an aviation environment:

- Altitude physiology.
- Spatial disorientation.
- Noise in Army aviation.
- Night vision.
- Illusions of flight.
- Stress and fatigue.
- Protective equipment.

- Health maintenance.
- Toxic hazards in aviation.

SPECIAL TRAINING

1-10. The unit commander must evaluate the missions of the unit to determine its special aeromedical training requirements. This analysis should include the following:

- Combat mission.
- Installation support missions.
- Contingency missions.
- Past requirements.
- Geographic and climatic considerations.
- Programmed training activities.

1-11. The supporting flight surgeon will help identify the aeromedical factors present during the various flight conditions and their effect on aircrews' performance. The flight surgeon and the unit commander will then develop a POI that meets the specific needs of the unit.

1-12. Commanders will include all crew members in the unit aeromedical training program. Without proper training and experience, the crew member may not understand individual limitations and the risks involved in the aviation environment.

RESPONSIBILITIES

THE U.S. ARMY SCHOOL OF AVIATION MEDICINE

1-13. USASAM, at Fort Rucker, Alabama, is responsible for planning supervising, and conducting all formal aeromedical U.S. Army aviation training programs. USASAM also advises and assists unit commanders and flight surgeons in developing local unit aeromedical training programs.

THE UNIT COMMANDER

1-14. The unit commander, assisted by the flight surgeon, will develop a local unit aeromedical training program. The program should be designed to meet the unit's mission requirements.

THE FLIGHT SURGEON

1-15. The flight surgeon provides medical support. He also assists the unit commander in developing, presenting, and monitoring a unit aeromedical training program.

REVALIDATION AND WAIVER

REVALIDATION

1-16. Aircrew members are required to stay current in aeromedical training and hypobaric (low-pressure/high-altitude) chamber training, according to

AR 95-1, TC 1-210, and the appropriate ATM. To meet ATP requirements if currency lapses, an aircrew member must undergo refresher training and reevaluation.

WAIVER

1-17. AR 95-1 contains waiver procedures.

TRAINING RECORD

1-18. When an aircrew member completes the prescribed qualification, the training record will be established, as explained below.

INITIAL AEROMEDICAL TRAINING

1-19. After the aircrew member has completed training, the following entry is to be made in the REMARKS section of the DA Form 759 (Individual Flight Record and Flight Certificate—Army): "Individual has completed initial physiological training prescribed in FM 1-301 including hypobaric (low-pressure/high-altitude) chamber qualification on (date)."

REFRESHER TRAINING

1-20. The REMARKS section of DA Form 759 should contain the following entry: "Individual has completed refresher physiological training including hypobaric (low-pressure/high-altitude) chamber qualification on (date)."

SPECIAL TRAINING BY OTHER SERVICES

1-21. When aeromedical training is conducted by the U.S. Air Force or U.S. Navy, the forms listed may be used to document the training qualification if DA Form 759 is not available. The appropriate entry will be made in the REMARKS section of the applicable form when the aircrew member completes training. The forms that other services may use are—

- AF1274 (Physiological Training).
- AF702 (Individual Physiological Training Record).
- NAVMED 6150/2 (Special Duty Medical Abstract).
- NAVMED 6410/7 (Completion of Physiological Training).

1-22. Appropriate entries will be made on an SF 600 (Health Record—Chronological Record of Medical Care), which is filed in the DA Form 3444-series (Terminal Digit File for Treatment Record). This information will document any medical difficulties that the individual may have encountered during altitude-chamber qualification.

Chapter 2

Altitude Physiology

Human beings are not physiologically equipped for high altitudes. To cope, we must rely on preventive measures and, in some cases, life-support equipment. Although Army aviation primarily involves rotary-wing aircraft flying at relatively low altitudes, aircrews may still encounter altitude-associated problems. These may cause hypoxia, hyperventilation, and trapped-gas and evolved-gas disorders. By understanding the characteristics of the atmosphere, aircrews are better prepared for the physiological changes that occur with increasing altitudes.

SECTION I – ATMOSPHERE

PHYSICAL CHARACTERISTICS OF THE ATMOSPHERE

2-1. The atmosphere is like an ocean of air that surrounds the surface of the Earth. It is a mixture of water and gases. The atmosphere extends from the surface of the Earth to about 1,200 miles in space. Gravity holds the atmosphere in place. The atmosphere exhibits few physical characteristics; however, it shields the inhabitants of the Earth from ultraviolet radiation and other hazards in space. Without the atmosphere, the Earth would be as barren as the moon.

STRUCTURE OF THE ATMOSPHERE

2-2. The atmosphere consists of several concentric layers, each displaying its own unique characteristics. Each layer is known as a sphere. Thermal variances within the atmosphere help define these spheres, offering aviation personnel an insight into atmospheric conditions within each area. Between each of the spheres is an imaginary boundary, known as a pause.

THE TROPOSPHERE

2-3. The troposphere extends from sea level to about 26,405 feet over the poles to nearly 52,810 feet above the equator. It is distinguished by a relatively uniform decrease in temperature and the presence of water vapor, along with extensive weather phenomena.

2-4. Temperature changes in the troposphere can be accurately predicted using a mean-temperature lapse rate of –1.98 degrees Celsius per 1,000 feet. Temperatures continue to decrease until the rising air mass achieves an altitude where temperature is in equilibrium with the surrounding atmosphere. Table 2-1 illustrates the mean lapse rate and the pressure decrease associated with ascending altitude.

Table 2-1. Standard Pressure and Temperature Values at 40 Degrees Latitude for Specific Altitudes

Altitude (feet)	Pressure (in/Hg)	Pressure (mm/Hg)	Pressure (psi)	Temperature (°C)	Temperature (°F)
Sea Level	29.92	760.0	14.69	15.0	59.0
10,000	20.58	522.6	10.11	–4.8	23.3
18,000	14.95	379.4	7.34	–20.7	–5.3
20,000	13.76	349.1	6.75	–24.6	–12.3
25,000	10.51	281.8	5.45	–34.5	–30.1
30,000	8.90	225.6	4.36	–44.4	–48.0
34,000	7.40	187.4	3.62	–52.4	–62.3
35,332	6.80	175.9	3.41	–55.0	–67.0
40,000	5.56	140.7	2.72	–55.0	–67.0
43,000	4.43	119.0	2.30	–55.0	–67.0
50,000	3.44	87.3	1.69	–55.0	–67.0

THE STRATOSPHERE

2-5. The stratosphere extends from the tropopause to about 158,430 feet (about 30 miles). The stratosphere can be subdivided based on thermal characteristics found in different regions. Although these regions differ thermally, the water-vapor content of both regions is virtually nonexistent.

2-6. The first subdivision of the stratosphere is termed the isothermal layer. In the isothermal layer, temperature is constant at –55 degrees Celsius (–67 degrees Fahrenheit). Turbulence, traditionally associated with the stratosphere, is attributed to the presence of fast-moving jet streams, both here and in the upper regions of the troposphere.

2-7. The second subdivision of the stratosphere is characterized by rising temperatures. This area is the ozonosphere. The ozonosphere serves as a double-sided barrier that absorbs harmful solar ultraviolet radiation while allowing solar heat to pass through unaffected. In addition, the ozonosphere reflects heat from rising air masses back toward the surface of the Earth, keeping the lower regions of the atmosphere warm, even at night during the absence of significant solar activity.

THE MESOSPHERE

2-8. The mesosphere extends from the stratopause to an altitude of 264,050 feet (50 miles). Temperatures decline from a high of –3 degrees Celsius at the stratopause to nearly –113 degrees Celsius at the mesopause.

2-9. Noctilucent clouds are another characteristic of this atmospheric layer. Made of meteor dust/water vapor and shining only at night, these cloud formations are probably due to solar reflection.

THE THERMOSPHERE

2-10. The thermosphere extends from 264,050 feet (50 miles) to about 435 miles above the Earth. The uppermost atmospheric region, the thermosphere is generally characterized by increasing temperatures; however, the temperature increase is in direct relation to solar activity. Temperatures in the thermosphere can range from –113 degrees Celsius at the mesopause to 1,500 degrees Celsius during periods of extreme solar activity.

2-11. Another characteristic of the thermosphere is the presence of charged ionic particles. These particles are the result of high-speed subatomic particles emanating from the sun. These particles collide with gas atoms in the atmosphere and split them apart, resulting in a large number of charged particles (ions).

COMPOSITION OF THE ATMOSPHERE

2-12. The atmosphere of the Earth is a mixture of gases. Although the atmosphere contains many gases, few are essential to human survival. Those gases required for human life are nitrogen, oxygen, and carbon dioxide. Table 2-2 indicates the percentage concentrations of gases commonly found in the atmosphere.

Table 2-2. Percentages of Atmospheric Gases

Gas	Symbol	Volume (%)
Nitrogen	N_2	78.0840
Oxygen	O_2	20.9480
Argon	A	0.9340
Carbon Dioxide	CO_2	0.0314
Neon	Ne	0.0018
Helium	He	0.0005
Hydrogen	H_2	<0.0001

NITROGEN

2-13. The atmosphere of the Earth consists mainly of nitrogen. Although a vital ingredient in the chain of life, nitrogen is not readily used by the human body. However, nitrogen saturates body fluids and tissues as a result of respiration. Aircrews must be aware of possible evolved-gas disorders because of the decreased solubility of nitrogen at higher altitudes.

OXYGEN

2-14. Oxygen is the second most plentiful gas in the atmosphere. The process of respiration unites oxygen and sugars to meet the energy requirements of the body. The lack of oxygen in the body at altitude will cause drastic physiological changes that can result in death. Therefore, oxygen is of great importance to aircrew members.

CARBON DIOXIDE

2-15. Carbon dioxide is the product of cellular respiration in most life forms. Although not present in large amounts, the CO_2 in the atmosphere plays a vital role in maintaining the oxygen supply of the Earth. Through photosynthesis, plant life uses CO_2 to create energy and releases O_2 as a by-product. As a result of animal metabolism and photosynthesis, CO_2 and O_2 supplies in the atmosphere remain constant.

OTHER GASES

2-16. Other gases—such as argon, xenon, and helium—are present in trace amounts in the atmosphere. They are not as critical to human survival as are nitrogen, oxygen, and carbon dioxide.

ATMOSPHERIC PRESSURE

2-17. Standard atmospheric pressure, or barometric pressure, is the force (that is, weight) exerted by the atmosphere at any given point. An observable characteristic, atmospheric pressure can be expressed in different forms, depending on the method of measurement. Atmospheric pressure decreases with increasing altitude, making barometric pressure of great concern to aircrews because oxygen diffusion in the body depends on total barometric pressure. Figure 2-1 illustrates the standard atmospheric pressure measurements at 59 degrees Fahrenheit (15 degrees Celsius) at sea level.

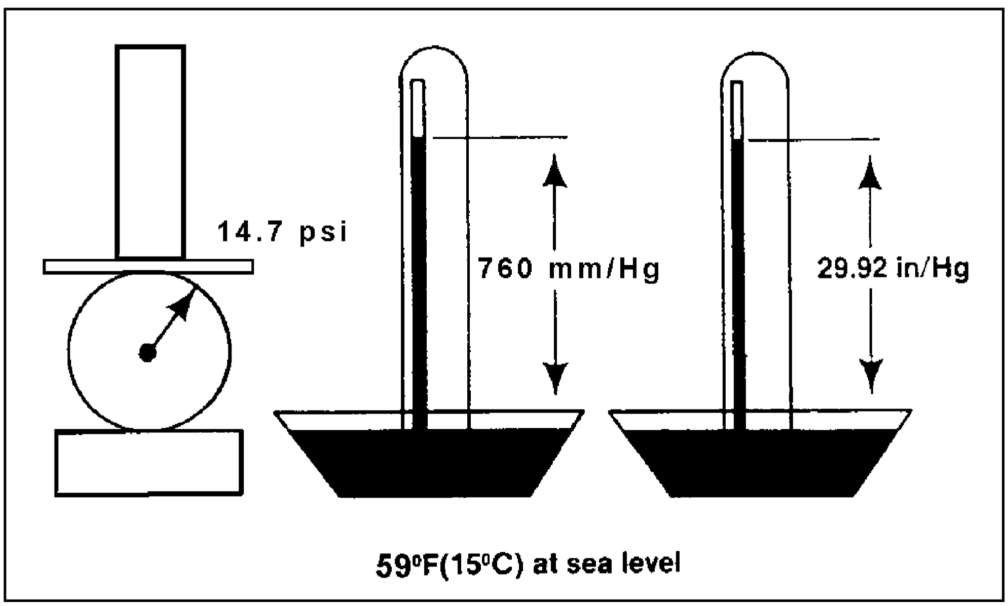

Figure 2-1. Standard Atmospheric Pressure Measurements at 59 Degrees Fahrenheit (15 Degrees Celsius) at Sea Level

DALTON'S LAW OF PARTIAL PRESSURES

2-18. A close relationship exists between atmospheric pressure and the amount of the various gases in the atmosphere. This relationship is referred to as Dalton's Law of Partial Pressures. Dalton's Law states that the pressure exerted by a mixture of ideal (nonreacting) gases is equal to the sum of the pressures that each gas would exert if it alone occupied the space filled by the mixture. The pressure of each gas within a gaseous mixture is independent of the pressures of the other gases in the mixture. The independent pressure of each gas is termed the partial pressure of that gas. Figure 2-2 represents the concept of Dalton's Law as related to the atmosphere of the Earth. Mathematically, Dalton's Law can be expressed as follows:

$$P_t = P_N + P_{O_2} + P_{CO_2} + \ldots \text{ (constant volume and temperature)}$$

Where P_t represents the total pressure of the mixture, P_N, P_{O_2}, P_{CO_2}, ... represent the partial pressures of each individual gas, V represents volume, and T represents temperature. To determine the partial pressure of the gases in the atmosphere (or any gaseous mixture whose concentrations are known), the following mathematical formula can be used:

Percentage of atmospheric

concentration *Total atmospheric*

of the individual gas x *pressure at a given altitude* =

100

Partial pressure of the individual gas

2-19. Dalton's Law states that the pressure exerted by a mixture of ideal (nonreacting) gases is equal to the sum of the pressures that each gas would exert if it alone occupied the space filled by the mixture. The pressure of each gas within a gaseous mixture is independent of the pressures of the other gases in the mixture. The independent pressure of each gas is termed the partial pressure of that gas. Figure 2-2 represents the concept of Dalton's Law as related to the atmosphere of the Earth.

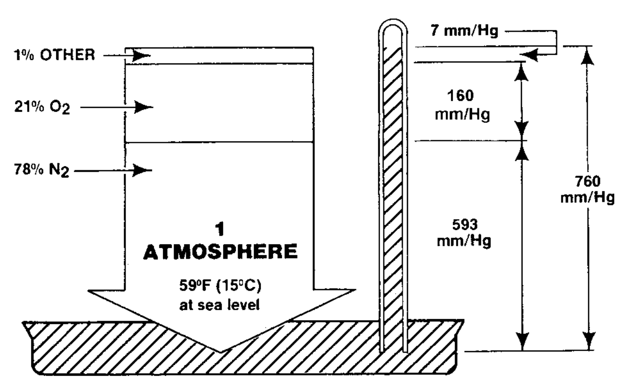

Figure 2-2. Dalton's Law of Partial Pressures as Related to the Atmosphere of the Earth

2-20. For the aircrew member, Dalton's law illustrates that increasing altitude results in a proportional decrease of partial pressures of gases found in the atmosphere. Although the percentage concentration of gases remains stable with increasing altitude, each partial pressure decreases in direct proportion to the total barometric pressure. Table 2-3 shows the relationship between barometric pressure and partial pressure.

Table 2-3. Partial Pressures of O_2 at Various Altitudes

Altitude (feet)	Atmospheric Pressure (mm/Hg)	PAO_2 (mm/Hg)	PVO_2 (mm/Hg)	Pressure Differential (mm/Hg)	Blood Saturation (%)
Sea Level	760	100	40	60	98
10,000	523	60	31	29	87
18,000	380	38	26	12	72
22,000	321	30	22	8	60
25,000	282	7	4	3	9
35,000	179	0	0	0	0

2-21. Changes in the partial pressure of oxygen dramatically affect respiratory functions within the human body. Any decrease in the partial pressure of oxygen quickly results in physiological impairment. Although this impairment may not be noticed initially at lower altitudes, the effects are cumulative and grow progressively worse as altitude increases.

2-22. Decreases in the partial pressure of nitrogen, especially at high altitude, can lead to a decrease in the solubility of N_2 in the body. This decrease in N_2 solubility can result in decompression sickness.

PHYSIOLOGICAL ZONES OF THE ATMOSPHERE

2-23. Humans are unable to adapt physiologically to all of the physical changes that occur in the different regions of the atmosphere. Because man evolved on the surface, humans are especially susceptible to the dramatic temperature and pressure changes that take place during ascent and sustained aerial flight. Because of these factors, the atmosphere can be further divided (by altitude) into three distinct physiological zones. These divisions are primarily based on pressure changes that occur within these parameters and the resultant effects on human physiology.

THE EFFICIENT ZONE

2-24. Extending upward from sea level to 10,000 feet, the efficient zone provides aircrews with a near-ideal physiological environment. Although the barometric pressure drops from 760 mm/Hg at sea level to 523 mm/Hg at 10,000 feet, Po_2 (partial pressure of oxygen) levels within this range allow humans to operate in the efficient zone without using protective equipment; however, sustained flight in the upper portions of this area may require acclimatization. Some minor problems associated with the efficient zone are ear and sinus blocks and gas expansion in the digestive tract. Also, without the use of supplemental oxygen, a decrease in night vision capabilities will occur above 4,000 feet.

THE DEFICIENT ZONE

2-25. The deficient zone of the atmosphere ranges from 10,000 feet at its base to 50,000 feet at its highest point. Because atmospheric pressure at 10,000 feet is only 523 mm/Hg, missions in the deficient zone carry a high degree of risk unless supplemental-oxygen/cabin-pressurization systems are used. As flights approach the upper limit of the deficient zone, decreasing barometric pressures (down to 87 mm/Hg) make trapped-gas disorders occur more frequently.

THE SPACE EQUIVALENT ZONE

2-26. Extending from 50,000 feet and continuing to the outer fringes of the atmosphere, the space equivalent zone is totally hostile to human life. Therefore, flight in the space equivalent zone requires a completely artificial atmospheric environment. Unprotected exposure to the extremely low temperatures and pressures found at these high altitudes can quickly result in death. An example of how dangerous this area can be is found at 63,000 feet (Armstrong's line). The barometric pressure at this altitude is only 47 mm/Hg, which equals the partial pressure of water in the body. At this pressure, water begins to "boil" within the body as it changes into a gaseous vapor.

SECTION II – CIRCULATORY SYSTEM

STRUCTURE AND FUNCTION OF THE CIRCULATORY SYSTEM

2-27. The circulatory system, shown in Figure 2-3, constitutes the physiologic framework required to transport blood throughout the body. A fundamental function of the circulatory system (along with the lymphatic system) is fluid transport. Other important functions of this system include meeting body cell nutrition and excretion demands, along with body-heat and electrochemical equilibrium requirements. Circulatory components include arteries, capillaries, and veins that stretch to nearly every cell in the body.

ARTERIES

2-28. Conducting blood away from the ventricles of the heart, the arteries are strong, elastic vessels that can withstand relatively high pressures. Arterial vessels generally carry oxygen-rich blood to the capillaries for use by the tissues.

CAPILLARIES

2-29. The body's smallest blood vessels, the capillaries, form the junction between the smallest arteries (arterioles) and the smallest veins (venules). Actually semipermeable extensions of the inner linings of the arterioles and venules, the capillaries provide body tissues with access to the bloodstream. Capillaries can be found virtually everywhere in the body, providing needed gas-/nutrient-exchange capabilities to nearly every body cell.

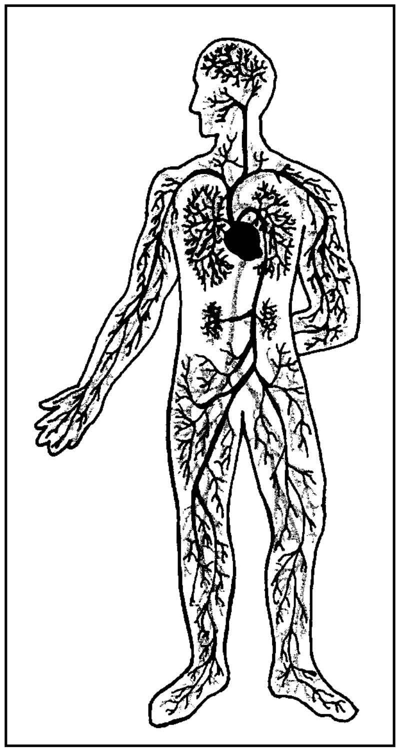

Figure 2-3. Structures of the Circulatory System

VEINS

2-30. Transporting blood from the capillaries back to the atria of the heart, the veins are the blood-return portion of the circulatory system. A low-pressure pathway, the veins also possess flap-like valves that ensure that blood flows only in the direction of the heart. In addition, the veins can constrict or dilate, based on the body's requirements. This unique ability allows blood flow and pressure to be modified, based on such factors as body heat or trauma.

COMPONENTS AND FUNCTIONS OF BLOOD

2-31. Although blood volume varies with body size, the average adult has a blood volume approaching 5 liters. About 5 percent of total body weight, blood is actually a form of connective tissue whose cells are suspended in a liquid intercellular material. The cellular portions of the blood compose about 45 percent of blood volume and consist mainly of red blood cells, white blood cells, and blood platelets. The remaining 55 percent of the blood is a liquid called plasma. Each of these components performs unique functions, summarized in Figure 2-4.

RED BLOOD CELLS

2-32. Most of the body's supply of oxygen is transported by the red blood cells (erythrocytes). Because oxygenation of red blood cells depends on the Po_2 in the atmosphere, aircrews may begin to suffer from oxygen deficiency (hypoxia) even at low altitudes. RBC structure, appearance, and production are among the factors that are affected when erythrocytes experience hypoxia.

2-33. Hemoglobin makes up about one-third of every red blood cell. Composed of several polypeptide chains and iron-containing heme groups, hemoglobin attracts oxygen molecules through an electrochemical magnetic process. Just as opposing poles on a magnet attract, so does the iron content (Fe^{2+}) within hemoglobin attract oxygen (O_2^{2-}).

2-34. When the blood supply is fully saturated with oxygen, as in arterial blood, blood takes on a bright-red color as oxyhemoglobin is formed. As blood passes through the capillaries, it releases oxygen to the surrounding tissues. As a result, deoxyhemoglobin forms and gives venous blood a dark-red color.

2-35. Red blood cells are produced in the red bone marrow. The number of RBCs in circulating blood is relatively stable; however, environmental factors play a large role in determining the actual RBC count. Smoking, an inadequate diet, and the altitude where one lives all contribute to fluctuations in RBC count. In fact, people residing above 10,000 feet may have up to 30 percent more erythrocytes than those living at sea level.

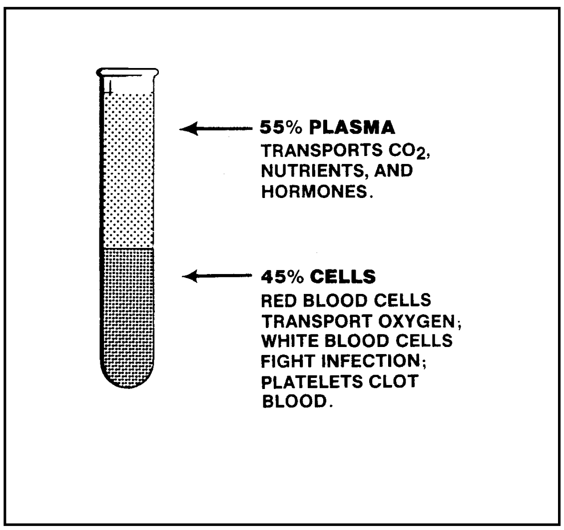

Figure 2-4. Functions of Blood Components

WHITE BLOOD CELLS

2-36. The principal role of the white blood cells, or leukocytes, is to fight/control various disease conditions, especially those caused by invading microorganisms. Although WBCs are typically larger than RBCs, WBCs can squeeze between the cells of blood vessels to reach diseased tissues. WBCs also help form natural immunities against numerous disease processes.