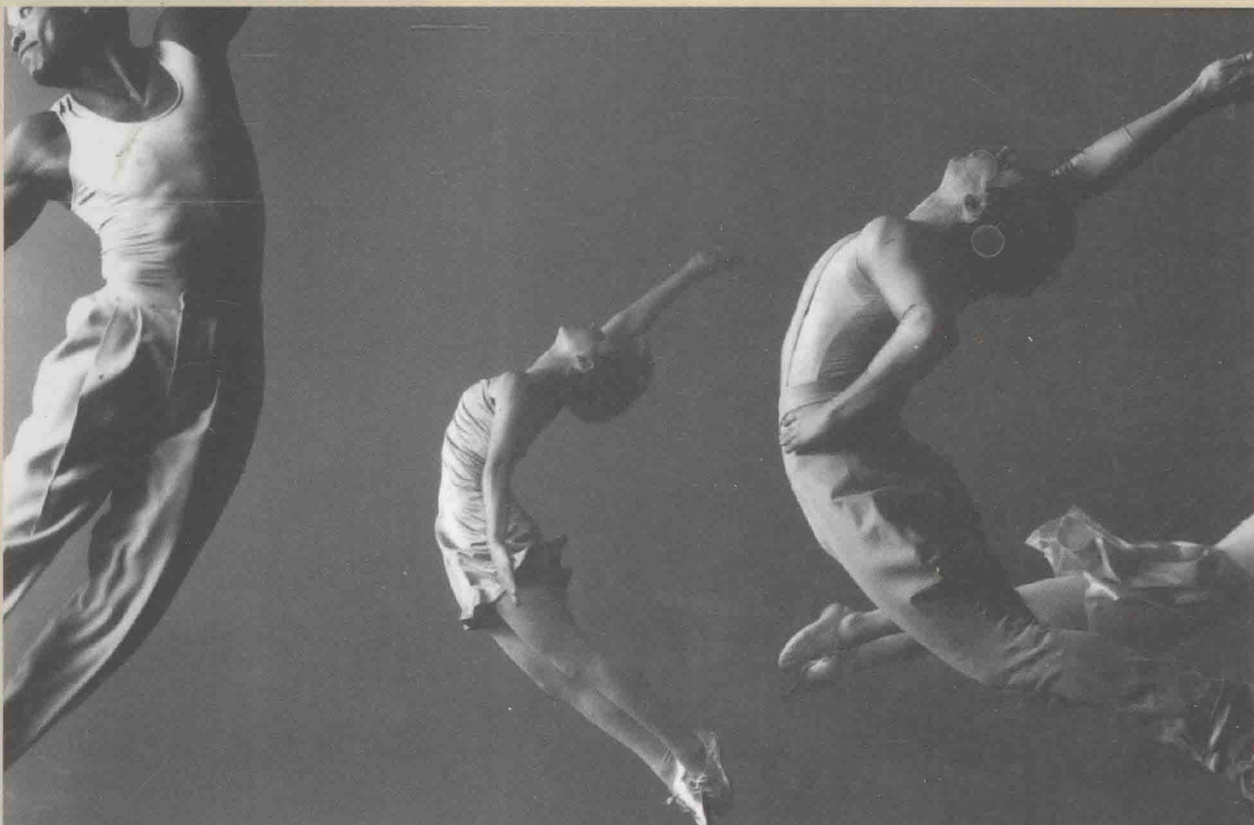
APPLICATIONS MANUAL

FREDERIC H. MARTINI, PH.D.
KATHLEEN WELCH, M.D. / MARTHA NEWSOME, D.D.S.



FUNDAMENTALS OF ANATOMY & PHYSIOLOGY

THIRD EDITION

FREDERIC H. MARTINI

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Fundamentals of Anatomy and Physiology

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Cover Photograph: *Lois Greenfield* ©

A Simon & Schuster Company
Upper Saddle River, New Jersey 07458

Printed in the United States of America
10 9 8 7 6 5 4

ISBN 0-13-341009-9

Prentice-Hall International (UK) Limited, *London*
Prentice-Hall of Australia Pty. Limited, *Sydney*
Prentice-Hall Canada Inc., *Toronto*
Prentice-Hall Hispanoamericana, S.A., *Mexico*
Prentice-Hall of India Private Limited, *New Delhi*
Prentice-Hall of Japan, Inc., *Tokyo*
Simon & Schuster Asia Pte. Ltd., *Singapore*
Editora Prentice-Hall do Brasil, Ltda., *Rio de Janeiro*

Applications Manual

Fundamentals of Anatomy and Physiology

Preface

This *Applications Manual* is a unique companion volume to the third edition of *Fundamentals of Anatomy and Physiology*. The creation of the manual was stimulated by the belief that an introductory text in this field should do more than explain the mechanics of physiological systems. It should also serve as the focal point for practical information that will be of value to students in their academic studies, their personal lives, and their professional careers. To meet these objectives, the applied material must be clear and concise, yet comprehensive enough to avoid errors caused by oversimplification. At the same time, the availability of this supplementary information should not interfere with the flow of essential text material concerning normal anatomy and physiology. The creation of a companion volume was thus a logical step, and a *Clinical Manual* accompanied the second edition of *Fundamentals of Anatomy and Physiology*.

This *Applications Manual* has evolved significantly from the original *Clinical Manual*. Together with the boxed essays and Clinical Discussions in the text, the discussions in the *Applications Manual* provide an introduction to the major pathological conditions and diagnostic procedures encountered in clinical practice. Not only has the treatment of clinical topics been greatly expanded and reorganized, but extensive pedagogical material has been added, along with a Scanning Atlas and a Cadaver Atlas. The aim has been to make this manual more useful as a supplement to the text, as a learning tool in its own right, and as a reference. (Further details on the organization can be found in the "To the Student" section that follows.)

Few instructors are likely to cover all of the material in the *Applications Manual*. Indeed, some instructors may choose not to cover all of the boxed material in the text. Because courses differ in their emphases and students differ in their interests and backgrounds, the goal in designing the AM has been to provide maximum flexibility of use. The diversity of applied topics in the text discussions and boxes, the *Applications Manual*, and the *New York Times* articles provide instructors with a wide variety of ways in which to integrate the treatment of normal function, pathology, and other clinical or health-related topics. Boxed material and topics in the *Applications Manual* that are not covered in class can be assigned, suggested, used for reference, or left to the individual student. Experience with the *Clinical Manual* of the second edition has shown that each student will find and read those selections that deal with disorders affecting friends or family, address topics of current interest and concern, or include information relevant to a chosen career path.

TO THE STUDENT

This *Applications Manual* is organized in units dealing with a wide variety of applied topics.

- **An Introduction to Diagnostics** discusses the basic principles involved in the clinical diagnosis of disease states.
- **A Frame of Reference for Anatomy and Physiology** provides historical perspectives on the sciences of anatomy and physiology, information about their vocabulary, and an introduction to the scientific method.
- **Applied Research Topics** considers principles of chemistry and cellular biology that are important to understanding, diagnosing, or treating homeostatic disorders.
- The **Body Systems** section, organized to parallel the text chapter by chapter and system by system, includes more detailed discussions of many clinical topics introduced in the text, along with discussions of additional diseases and diagnostic techniques not covered in the text. Each discussion is cross-referenced to the text; relevant chapter numbers in *Fundamentals of Anatomy and Physiology* are indicated by thumb tabs that appear in the page margins.
  - The Critical Thinking Questions that occur at the end of each system help you to sharpen your ability to think analytically.
  - Clinical Problems, placed after groups of related systems, assist you in integrating information about several different body systems and enable you to practice making reasonable inferences in realistic clinical situations.
- The **Case Studies** that follow the Body Systems section provide further opportunities for you to develop your powers of analysis, integration, and problem-solving. The studies presented, based on actual case histories, draw on material from the entire text (as they would in real life). The questions, keyed to crucial points in the presentation, help you to identify the relevant facts and form plausible hypotheses. You can use the case studies as the basis for discussion with other students or tackle them yourself to hone your skills.
- A **Scanning Atlas** of photographs produced by various modern imaging techniques lets you view the interior of the human body section by section. These images will help you to develop a better understanding of three-dimensional

relationships within the body. The Scanning Atlas includes a number of unlabeled images. By labeling them yourself, you can test your knowledge of anatomical structure while developing your powers of visualization in three dimensions.

- A full-color **Cadaver Atlas** of dissection photographs allows you to visualize the internal structure of all major body regions and organs. A selection of surface anatomy photographs of live models is included for comparison with the dissection views.

There are many different ways in which the material in the *Applications Manual* can be used. For example:

- You can read the *Applications Manual* simultaneously with *Fundamentals of Anatomy and Physiology*, referring to topics as each is referenced in the text.
- You can read the *Applications Manual* separately, referring to the text for relevant background information as needed.
- You can use the *Applications Manual* as a reference, reading only those discussions that are of personal interest to you, that are relevant to your proposed career, or that you need to research for some special purpose.

This manual was written with the student in mind, and student feedback was important in its design. If you have additional suggestions or comments, please to not hesitate to contact the authors at the address below.

ACKNOWLEDGMENTS

This was a complex project, and we would like to thank those who helped bring it to completion. Our students provided invaluable suggestions and support. Linda Schreiber coordinated the assembly of all of the components, and still found time to manage the review process. We are also indebted to our reviewers, Ruby Fogg of New Hampshire Technical Institute and Bill Nicholson of the University of Arkansas at Monticello, who provided constructive comments. Frederic Martini and Kathleen Welch would like to acknowledge Dr. Eugene C. Wasson, III, the staff of Maui Radiology Consultants, and the Radiology Department of Maui Memorial Hospital for providing the MRI and CT scans for the Scanning Atlas, and Ralph Hutchings, who contributed the photographs for the Cadaver Atlas. Martha Newsome is grateful for the love and support of her husband and children during the sometimes grueling writing process, and offers thanks in the memory of her best friend, Beth Peavy, who encouraged her to strive for excellence during their fifteen years of friendship. Finally, we would also like to express our thanks to David Brake, Executive Editor for Biology, for supporting this rather unconventional project; to Dan Schiller, Senior Development Editor, for coming through in a pinch, as usual; to Naomi Sysak, Supplements Production Editor; and to John Nestor, Veronica Schwartz, Liz Nemeth, and the rest of the production staff who worked on the design, layout, and assembly of this manual.

Of course, any errors or omissions are attributable to the authors, rather than to the reviewers. Readers with comments, suggestions, relevant reprints, or corrections should contact the authors at the address below.

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KEY TO ICONS USED IN THE APPLICATIONS MANUAL

 = **Reference Material**

 = **Topics Relating To the Diagnosis of Disease**

 = **Disorders and Clinical Syndromes**

℞ = **Drugs and Treatment Methods**

 = **Exercise and Sports-related Topics**

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An Introduction to Diagnostics

Each of us has made simple diagnoses in our everyday experiences. When the car won't start, the kitchen faucet leaks, or the checkbook doesn't balance, most people will try to determine the nature of the problem. Sometimes the diagnosis is simple: the car battery is dead, the faucet is not completely turned off, or the amount of a check (or a deposit) was recorded incorrectly. Once the diagnosis is made, steps can be taken to remedy the situation.

Most people use similar observational skills to diagnose simple medical conditions. For example, imagine that you awaken with a headache, feeling weak and miserable. On arising you gaze at yourself in the bathroom mirror. Your face is flushed, your forehead is hot to the touch, and swallowing is painful. You know that these correspond to the general symptoms of the flu, and you also know that your lab partner missed Tuesday's class because of the flu. You diagnose yourself as sick with the flu, and you open the medicine cabinet in search of appropriate medication.

The steps taken in arriving at the conclusion "I've probably got the flu" were quite straightforward: (1) you made observations about your condition, (2) you compared your observations with available data, and (3) you determined the probable nature of the problem. Clinical diagnosis can be much more complicated, but these same steps are always required. In this section we will examine the basic principles of diagnosis. The goal is not to train you to be a clinician, but rather to demonstrate how these basic steps can be followed in a clinical setting.

Homeostasis and Normal Values FAP *p. 16*

The central principle of physiology is that physiological systems strive to maintain a relatively constant internal environment. Homeostatic control mechanisms are both flexible and dynamic. They operate to keep vital characteristics within the relatively narrow limits required for normal function. Examples include the mechanisms responsible for controlling levels of oxygen, carbon dioxide, glucose, pH, blood pressure, and other factors. As noted in Chapter 1 (FAP, *p. 15)*, physiological values usually oscillate within a normal range of values. For this reason most laboratory reports indicate the values determined and the normal ranges for each value.

In many cases, the ranges can change over time (from infancy to old age) or from moment to moment, depending on the activity underway. For example, people often use 72 beats per minute (bpm) as a representative heart rate. That value is actually the average for young adults at rest. The real, measured values can be quite different. This becomes very apparent when you consider the normal *ranges*. The typical heart rate of resting young adults (60-80 bpm) differs from that of infants (70-170 bpm), and the adult heart rate during deep sleep (45-60 bpm) is very different from that found during heavy exercise (160-180 bpm).

HOMEOSTATIC FAILURE FAP *p. 16*

The ability to maintain homeostasis depends on two interacting factors: (1) the status of the physiological systems involved and (2) the nature of the stress imposed. Homeostasis is a balancing act, and each person is like a tightrope walker. Homeostatic systems must adapt to sudden or gradual changes in the environment, the arrival of pathogens, accidental injuries, and many other factors, just as a tightrope walker must make allowances for gusts of wind, frayed segments of the rope, and thrown popcorn.

The ability to maintain homeostatic balance varies with the age, general health, and genetic makeup of the individual. The geriatric patient or young infant with the flu is in much greater danger than an otherwise healthy young adult with the same viral infection. If homeostatic mechanisms cannot cope with a particular stress, physiological values will begin to drift outside of the normal range. This can ultimately affect all other systems, with potentially fatal results; after all, a person unable to maintain balance will eventually fall off the tightrope.

Consider a specific example. A young adult exercising heavily may have a heart rate of 180 bpm for several minutes. But such a heart rate can be disastrous for an older person already suffering from cardiovascular and respiratory problems. If the heart rate cannot be reduced, due to problems with the pacemaking or conducting systems of the heart, there will be damage to the cardiac muscle tissue, leading to decreased pumping efficiency and a fall in blood pressure.

This represents a serious threat to homeostasis. Other systems soon become involved, and the situation worsens. Filtration at the kidneys occurs at the normal range of arterial blood pressures. When the blood pressure becomes abnormally low, blood flow through peripheral tissues declines, and the kidneys stop working. Toxins then begin accumulating in the circulation. The reduced blood flow in other tissues soon leads to a generalized *hypoxia*, or low tissue oxygen level. Cells throughout the body then begin to suffer from oxygen starvation. The person is now in serious trouble, and unless steps are taken to correct the situation, survival is threatened.

HOMEOSTASIS AND DISEASE

Disease is the failure to maintain homeostatic conditions. The disease process may initially affect a tissue, an organ, or a system, but it will ultimately lead to changes in the function or structure of cells throughout the body. A disease can often be overcome through appropriate, automatic adjustments in physiological systems. In a case of the flu, the disease develops because the immune system cannot defeat the virus before it has infected cells of the respiratory passageways. For most people, the physiological adjustments made in response to the presence of this disease will lead to the elimination of the virus and the restoration of homeostasis. Some diseases cannot be easily overcome. In the case of the person with acute cardiovascular problems, some outside intervention must be provided to restore homeostasis and prevent fatal complications.

Diseases may result from:

- *Pathogens or parasites that invade the body:* Examples include the flu, mumps, measles, pinworms, and tapeworms.
- *Inherited genetic conditions that disrupt normal physiological mechanisms:* These conditions make normal homeostatic control difficult or impossible. Examples noted in later sections include the *lysosomal storage diseases* and *sickle cell anemia.*
- *The loss of normal regulatory control mechanisms:* For example, cancer involves the rapid, unregulated multiplication of abnormal cells. Many cancers have been linked to abnormalities in genes, responsible for controlling the rates of cell division. A variety of other diseases, called *autoimmune disorders,* result when regulatory mechanisms of the immune system fail, and normal tissues are attacked.
- *Degenerative changes in vital physiological systems:* Many systems become less adaptable and less efficient as part of the aging process. For example, there are significant reductions in bone mass, respiratory capacity, cardiac efficiency, and kidney filtration as part of the aging process. If these individuals are exposed to stresses that their weakened systems cannot tolerate, disease results.
- *Trauma, toxins, or other environmental hazards:* Accidents may damage internal organs, impairing their function. Toxins consumed in the diet or absorbed through the skin may disrupt normal metabolic activities.
- *Nutritional factors:* Diseases may result from diets inadequate in proteins, essential amino acids, essential fatty acids, vitamins, minerals, or water. Kwashiorkor, a protein deficiency disease, and scurvy, a disease caused by vitamin C deficiency, are two examples. Excessive consumption of high-calorie foods, fats, or fat-soluble vitamins can also cause disease.

Pathology is the study of disease, and *pathophysiology* is the study of functional changes caused by disease. Different diseases can often result in the same alteration of function and produce the same symptoms. For example, a patient with pale skin and complaining of a lack of energy and breathlessness may have (1) respiratory problems that prevent normal oxygen transfer to the blood, as in *emphysema,* or (2) cardiovascular problems that interfere with normal oxygen transport *(anemia)* or circulation (heart failure). Clinicians must ask questions and collect appropriate information to make a proper diagnosis.

This often involves eliminating possible causes until a specific diagnosis is reached.

For example, if tests indicate that anemia is responsible for the these symptoms, the specific type of anemia must then be determined before treatment can begin. After all, the treatment for anemia due to a dietary iron deficiency will be very different from the treatment for anemia due to internal bleeding. Of course, you could not hope to identify the probable cause of the anemia unless you were already familiar with the physical and biochemical structure of red blood cells, and their role in the transport of oxygen. This brings us to a key concept: *All diagnostic procedures assume an understanding of normal anatomy and physiology.*

SYMPTOMS AND SIGNS

When disease processes affect normal functions, the alterations are called the *symptoms* and *signs* of the disease. An accurate diagnosis, or identification of the disease, is accomplished through the observation and evaluation of signs and symptoms.

A **symptom** is the patient's perception of a change in normal body function. Examples of symptoms include nausea, malaise, and pain. Symptoms are difficult to measure, and one must rely on asking appropriate questions. Examples of typical questions include:

"When did you first notice this symptom?"

"What does it feel like?"

"Does it come and go, or does it always feel the same?"

"Are there things you can do to make it feel better or worse?"

The answers provide information on the duration, sensations, recurrence, and potential triggering mechanisms for the symptoms important to the patient.

Pain, an important symptom of many illnesses, is often an indication of tissue injury. The flow chart in Figure A-1 demonstrates the types of pain and introduces important related terminology. Pain sensations and pathways are detailed in Chapter 17 of the text, and the control of pain is considered in related sections of the *Applications Manual* (p. 95).

A **sign** is a physical manifestation of the disease. Unlike symptoms, signs can be measured and observed through sight, hearing, or touch. The yellow color of the skin caused by liver dysfunction or a detectable breast lump are signs of disease. An observable change due to a disturbance in the structure of tissue or cells is called a **lesion.** Lesions of the skin are considered in detail in a later section dealing with the integumentary system (p. 44).

Steps in Diagnosis

A person experiencing serious symptoms usually seeks professional help, and thereby becomes a patient. The consultant, whether a nurse, physician, or emergency medical technician, must determine the need for medical care based on observation and assessment of the patient's symptoms and signs. This is the process of diagnosis: the identification of a pathological process by its characteristic symptoms and signs.

Diagnosis is a lot like assembling a jigsaw puzzle. The more pieces (clues) available, the more complete the picture will be. The process of diagnosis is one of deduction and follows an orderly sequence of steps:

1. *The medical history of the patient is obtained:*

   The medical history is a concise summary of past medical disorders, general factors that may affect the function of body systems, and the health of the family. This information provides a framework for considering the individual's current problem. The examiner gains information about the person's concerns by asking specific questions and using good listening skills. Physical assessment begins here, and this is the time for unspoken questions like, "Is this person moving, speaking, and thinking normally?" The answers will later be integrated with the results of more precise observations.

   Other components of the medical history may include the following.

   - *Chief complaint:* The person, now a patient, is asked to specify the primary problem that requires attention. This is recorded as the *chief complaint.* An example would be the entry "Patient complains of pain in the right lower quadrant."
   - *Onset of symptoms:* When did the patient first notice the symptoms? The duration of the disease process is an important factor. For example, an infection may have been present for months, only gradually increasing in severity. This would be called a *chronic infection.* Chronic infections may be treated differently from an *acute infection* that produces sudden, intense symptoms. A disease process may have been underway for some time before the person recognizes that a problem exists. Over the initial period the individual experiences mild *subclinical symptoms* that are usually ignored.
   - *Review of systems:* The patient is asked questions that focus on the general status of each body system. This process may detect related problems or causative factors. For example, a chief complaint of

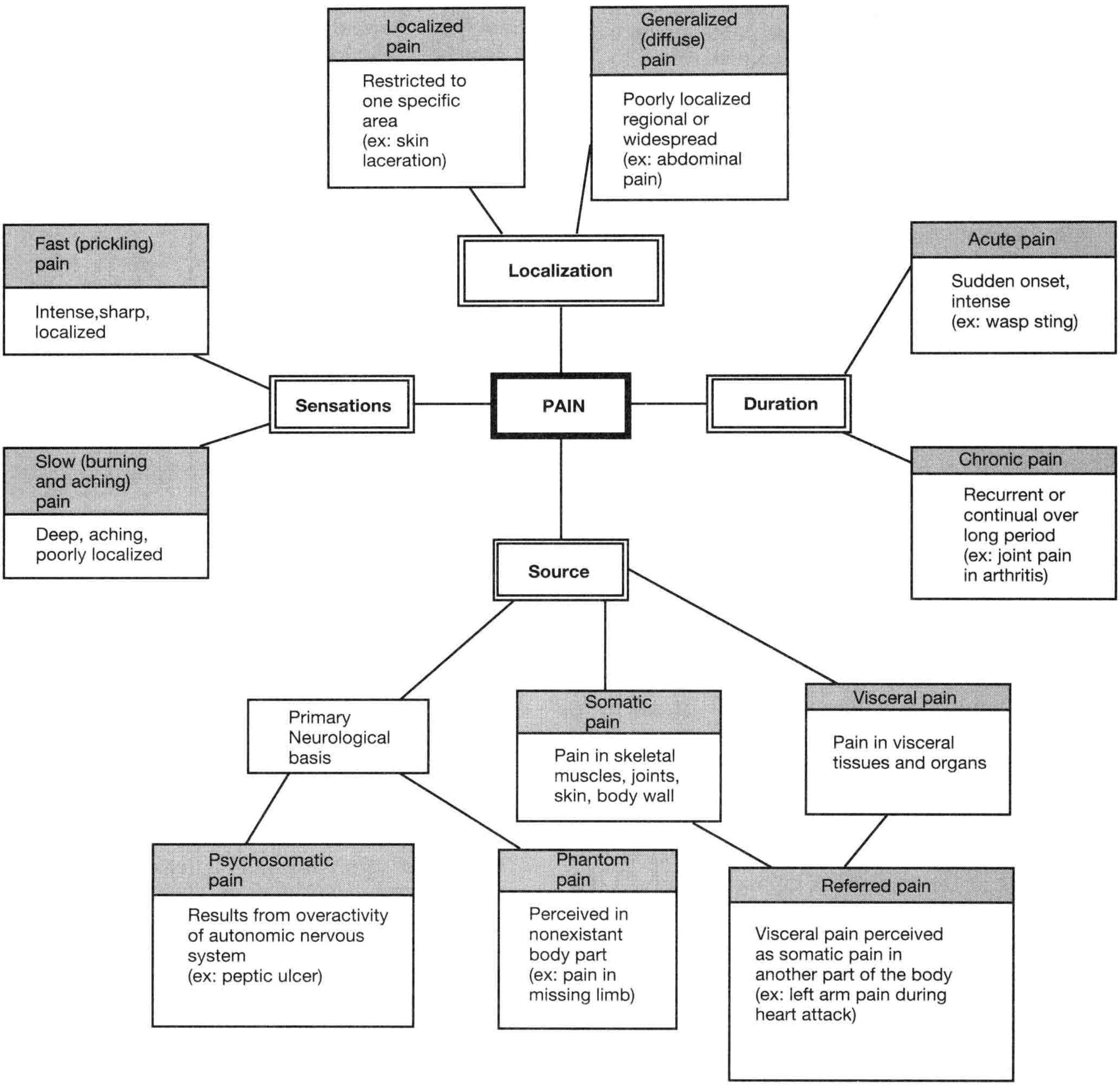

Figure A–1 Methods of Classifying and Describing Pain.

headache pain may be *related* to visual problems (stars, spots, blurs, or blanks seen in the field of vision) or *caused* by visual problems (eyeglasses poorly fitted, or having the wrong prescription).

2. *A physical examination is performed:* The physical examination is a basic but vital part of the diagnostic process. The common techniques used in physical examination include *inspection* (vision), *palpation* (touch), *percussion* (tapping), and *auscultation* (listening).

   - **Inspection** is careful observation. A general inspection involves examining body proportions, posture, and patterns of movements. Local inspection is the examination of sites or regions of suspected disease. Of the four components of the physical exam, inspection is often the most important because it provides the largest amount of useful information. Many diagnostic conclusions can be made on the basis of inspection alone; most skin conditions, for example, are identified in this way. A number of endocrine problems and inherited metabolic disorders can produce subtle changes in body proportions that can be detected by the trained eye.

- In **palpation** the clinician uses hands and fingers to feel the body. This procedure provides information on skin texture and temperature, the presence of abnormal tissue masses, the pattern of the pulse, and the location of tender spots. Once again, the procedure relies on an understanding of normal anatomy. A small, soft, lumpy mass in one spot is a salivary gland; in another location it could be a tumor. A tender spot is important in diagnosis only if the observer knows what organs lie beneath it.
- **Percussion** is tapping with the fingers or hand to obtain information about the densities of underlying tissues. For example, the chest normally produces a hollow sound, because the lungs are filled with air. That sound changes in pneumonia, when the lungs contain large amounts of fluid. Of course, to get the clearest chest percussions, the fingers must be placed in the right spots.
- **Auscultation** (aws-kul-TĀ-shun; *auscultare,* to listen) is listening to body sounds, often using a stethoscope. This technique is particularly useful for checking the condition of the lungs during breathing. The wheezing sound heard in asthma is caused by constriction of the airways, and pneumonia produces a gurgling sound, indicating that fluid has accumulated in the lungs. Auscultation is also important in diagnosing heart conditions. Many cardiac problems affect the sound of the heartbeat or produce abnormal swirling sounds during blood flow.

Every examination also includes measurements of certain vital body functions, including body temperature, blood pressure, respiratory rate, and heart (pulse) rate. The results, called **vital signs,** are recorded on the patient's chart. As noted earlier, each of these values can vary over a normal range that differs according to the age, sex, and general condition of the individual. Table A-1 indicates the representative ranges for vital signs in infants, children, young adults, and persons over age 60.

3. *If necessary, diagnostic procedures are performed:* The physical examination alone may not provide enough information to permit a precise diagnosis. Diagnostic procedures can then be used to focus on abnormalities revealed by the physical examination. For example, if the chief complaint is knee pain after a fall, and the physical examination reveals swelling and localized, acute pain on palpation, the *preliminary diagnosis* may be a torn cartilage. MRI scan may be performed to ensure that there are not other problems, such as torn ligaments. With the information provided from the diagnostic procedure, the *final diagnosis* can be made with reasonable confidence. Diagnostic procedures thus extend, rather than replace, the physical examination.

Table A-1 Normal Range of Values for Resting Individuals in Different Age Groups

Vital Sign	*Infant (3 months)*	*Child (10 years)*	*Adult*
Blood Pressure (mm Hg)	90/50	125/60	95/60 to 140/90
Respiratory Rate (per minute)	30-50	18-30	8-18
Pulse Rate (per minute)	70-170	70-110	50-95

There are two general categories of diagnostic procedures.

1. Tests performed on the individual, usually within a hospital facility. Information on representative tests of this type is summarized in Table A-2. These procedures allow the clinician to
   - Visualize internal structures (endoscopy, x-rays, scanning procedures, ultrasonography, mammography)
   - Monitor physiological processes (EEG, ECG, PET, RAI, pulmonary function tests)
   - Assess the patient's homeostatic responses (stress testing, skin tests)
2. Tests performed in a clinical laboratory on tissue samples, body fluids, or other materials collected from the patient. Table A-3 includes details on a representative sample of such tests.

THE PURPOSE OF DIAGNOSIS

Several hundred years ago, a physician would arrive at a final diagnosis and consider the job virtually done. Once the diagnosis was made, the patient and family would know what to expect. In effect, the physician was more of an oracle than a healer. Wounds could be closed, and limbs amputated, but there were few effective treatment options available. Therapy largely consisted of some combination of cupping and bleeding, often performed by barbers rather than surgeons.

We have an incredible variety of treatment options today, and a final diagnosis is vital because it determines what treatment options will be selected. A modern physician with a new patient follows the *SOAP* protocol:

Table A-2 Representative Diagnostic Tests, their Principles and Uses.

Procedure	*Principle*	*Examples of Uses*
Endoscopy	Insertion of fiber optic tubing into body orifice or through a small incision (laparoscopy and arthroscopy); permits visualization of body cavity or organ interior.	Allows direct visualization of internal structures and detection of abnormalities of surrounding soft tissue. Bronchoscopy: bronchus and lungs Laparoscopy: abdominopelvic organs Cystoscopy: urinary bladder Esophagoscopy: esophagus Gastroscopy: stomach Colonoscopy: colon Arthroscopy: joint cavity
Standard X-rays	A beam of X-rays passes through the body and then strikes a photographic plate. Radiodense tissues block X-ray penetration, leaving unexposed (white) areas on film negative. (FAP, *p.25*)	Longbones: to detect fracture, tumor, growth patterns. Chest: to detect tumors, pneumonia, atelectasis, tuberculosis. Skull: to detect fractures, sinusitis, metastatic tumors.
Contrast X-rays	X-rays taken after infusion or ingestion of radiodense solutions. (FAP, *p.25*)	Barium Swallow (upper GI): Series of x-rays following the ingestion of barium, to detect abnormalities of esophagus, stomach, and duodenum. Barium Enema: series of x-rays following barium enema to detect abnormalities of colon. IV Pyelography: Series of x-rays following intravenous injection of radiopaque dye filtered by kidneys; reveals abnormalities of kidneys, ureters, and bladder; allows assessment of renal function. Mammogram: x-rays of each breast taken at different angles for early detection of breast cancer and other masses, such as cysts.
Computerized Tomography (CT or CAT)	Produces cross-sectional images of area to be viewed; all sections together can produce a three-dimensional image for detailed examination (FAP, *p.26*).	CT Scans of the head, abdominal region, (liver, pancreas, kidney), chest and spine are taken to assess organ size and position, to determine progression of a disease, and for detection of abnormal masses.
Nuclear Scans	Radioisotope ingested or injected into the body becomes concentrated in the organ to be viewed; gamma radiation camera records image on film. Area should appear uniformly shaded; dark or light areas suggest hyperactivity or hypoactivity of the organ.	Bone Scan: to detect tumors, infections, and degenerative diseases. Scans of the brain, heart, thyroid, liver, spleen, and kidney can be useful in assessing organ function and the extent of disease.
Radioactive Iodine Uptake Test (RAI)	Radioactive iodine is given orally and scans are taken at 3 different times to determine thyroid percentage uptake of radioiodine.	Aids in the determination of a hyperthyroid or hypothyroid condition.
Positron Emission Tomography (PET)	Radioisotopes are given by injection or inhalation; and gamma detectors absorb energy and transmit information to computers to generate cross-sectional images.	Used to measure metabolic activity of heart and brain, and to analyze blood flow through organs.