

review of basic science & clinical dentistry

Volume I basic science

editors

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REVIEW
OF
BASIC SCIENCE
AND
CLINICAL DENTISTRY

Volume I | Basic Science

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The authors and publisher have exerted every effort to ensure that drug selection and dosage set forth in this text are in accord with current recommendations and practice at the time of publication. However, in view of ongoing research, changes in government regulations, and the constant flow of information relating to drug therapy and drug reactions, the reader is urged to check the package insert for each drug for any change in indications and dosage and for added warnings and precautions. This is particularly important when the recommended agent is a new and/or infrequently employed drug.

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PREFACE

At present, over 50% of the licensing jurisdictions require candidates to pass Part I of the National Board Examinations. The American Association of Dental Examiners assists dental schools by distributing an outline of the subject matter covered in the basic sciences which comprise Part I. Furthermore, as it is composed of questions contributed by many dental schools, one can say that Part I of the National Board Examinations surveys aspects of the basic sciences curricula of the American dental schools.

Basic science educators are interested in the knowledge and skills taught in other schools as well as in sharing their own most recent academic developments. Such faculty are generally dedicated and committed individuals who strive not only to impart the “common body of biologic knowledge,” but also to develop in dental students the skills and attitudes needed to deliver excellent oral health care.

However, basic science educators feel a sense of frustration. Owing to a knowledge explosion in basic sciences as related to dentistry during the past decade, faculty feel that they are proceeding faster than the students are assimilating the material. Their concern is that, with little time for review, students do not retain enough content. This situation leads to *memorization* as opposed to *comprehension*. Yet, the students themselves are aware that memorization is not the approach best suited for the problem-oriented examination questions.

Dental students like to compare their performances with those of other dental students who take Part I of the Boards. Correspondingly, they are proud of their current affiliations and want their schools to compare favorably with other schools.

The primary emphasis of this volume of *Review of Basic Science and Clinical Dentistry* is to present specific content areas covered by Part I of the National Board Examinations. Authors well versed in the basic principles and current practices in dentistry have written about the basic sciences, as presented in the content outline from the American Association of Dental Examiners. The contributing authors have in-

corporated into each chapter representative questions similar to those in the National Boards. These questions present difficult cases and complex problems.

We also stress the students' need for a positive attitude, self-confidence, and mental readiness for problem-solving. Students should not rationalize their lack of knowledge by blaming the faculty, but should acknowledge that there are deficiencies in their storehouse of information. Acknowledged deficiencies require that the student accept responsibility for learning. Students can study this volume from the viewpoint of comprehension instead of memorization—that is, through synthesis of the principles of the basic sciences.

A secondary purpose of this volume is to establish or reinforce for both dental student and dentist that a grasp of biologic facts and concepts is crucial to the delivery of quality dental care. Consumer groups and the federal government are demanding accountability from allied health professionals. These groups have expended efforts in educating citizens to take care of their total health. As a result of increased availability of information and the attainment of higher levels of education by a larger percentage of the population, these citizens are now making more intelligent demands upon the dental practitioner. They expect dentists to demonstrate in practice a thorough understanding of structures, functions, and diseases of the oral cavity.

A note to the practitioner: to justify legally one's position as an expert, a practicing dentist must maintain a practical knowledge of his or her profession relative to biologic dentistry. There have been remarkable developments in dentistry over the past ten years; diagnosis, treatment, and the approach to treatment are significantly different now. For those who may be required to take state board dental examinations for relicensing, this volume will be a friend. It will be equally valuable in assessing one's own knowledge in terms of both past and present norms.

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HOW TO PREPARE FOR AND TAKE THE NATIONAL BOARDS:

SELF-ACTIVATION IS THE KEY TO SUCCESS

Diane M. Brown / Victor M. Coury

Because adequate and effective dental service must take into account biologic needs, students must develop a working knowledge of oral-systemic relationships in both health and disease, of the biologic significance of preventive, restorative, and prosthetic services, and of the interdependence of the dental practitioner and physician in coping with the total health needs of the patient and community. Societal trends, which assist the dental educator in the identification of dental requirements, are making the following demands upon the practitioner: 1) the individual must demonstrate in practice a thorough understanding of the structures, functions, and diseases of the mouth; 2) the individual must be able to deliver dental treatment according to published criteria for acceptable dental procedures; and 3) the individual must be able to defend the dental treatment.

It is generally agreed that the dental graduate must be able to meet certain basic objectives. For example, the graduate must be able to:

1. Develop a sound diagnosis and treatment plan
2. Perform acceptable restorative procedures
3. Detect, diagnose, and manage an oral cancer patient
4. Evaluate the safety in use of dental materials
5. Detect, diagnose, and treat periodontal problems
6. Manage a dental emergency
7. Adjust occlusion for oral harmony
8. Administer myofunctional therapy for temporomandibular joint (TMJ) disorders
9. Establish safeguards against mercury vaporization, radiation scatter, and transference of hepatitis
10. Utilize auxiliaries efficiently
11. Manage dental office personnel
12. Manage patients according to established principles of human behavior

The National Board Dental Examinations aid in the evaluation of these abilities by attempting to 1) survey

and evaluate the curricula of dental schools, 2) offer each student the results as to the level of his or her basic knowledge of dentistry in comparison to the national population of dental students, and 3) assess the problem-solving abilities of students. The National Board Examinations, which cover the material taught in all 59 dental colleges, are divided into two sections, the first of which has four tests.

Part I

Anatomic Sciences
Biochemistry and Physiology
Microbiology and Pathology
Dental Anatomy

It is to be noted that in the Anatomic Sciences test the following content areas will be tested: gross anatomy, histology, embryology, head and neck anatomy, and neuroanatomy. For the Pathology test, it is advisable to consult with your oral pathology instructor in order to determine oral pathology content. This is clearly indicated in the Outlines of the National Board Examinations, 1977-78.

Students should be aware that the Part I examination on Dental Anatomy includes a minimum of 20 questions on occlusion.

A revision in National Board regulations allows a student who fails one or more examinations to take a reexamination in individual subjects only if the student's average score is 75 or higher. Students who earn average scores below 75 are required to repeat the entire part. For example, scores of 85, 75, 60, and 76 on the four tests of Part I indicate that the student passed three of the four tests. The average of these seven tests, however, is 74; the student is therefore required to repeat the entire examination.

Presently, 28 of 53 licensing jurisdictions require a student to pass both Parts I and II to be a licensed

dentist. All portions of Part I must be passed before a student may take Part II; there are no exceptions.

CAN YOU PREPARE YOURSELF TO TAKE THE NATIONAL BOARD EXAMINATIONS?

Yes, you certainly can. Although this volume is not a complete dental education in itself, it is a high quality review.

To prepare for the tests you must motivate yourself and get into a frame of mind for learning. It has been demonstrated that studies initiated and pursued by an individual with a clear goal in mind are the most successful. Self-motivation is a key to success. This volume will give you the self-confidence you need to succeed.

This book will also give you the feel of the examinations. The content in this volume follows the content outline of the National Boards. The practice questions are problem-solving, multiple choice questions similar to those found in the National Boards. In answering them you will add to your knowledge by learning the correct answers. This will help you to remember much you thought you had forgotten.

There is no substitute for knowledge in the specific content areas; test-taking technique or guessing will not earn a passing score. This review will test your level of knowledge by assessing your areas of strength and weakness. Weak content areas can be explored further for new learning.

WHAT IS THE BEST WAY TO PREPARE FOR THE NATIONAL BOARD EXAMINATIONS?

The best general rule for taking any examination is to "be prepared." This means having a thorough mastery of the material, and having it so well organized that you can recall it in any form requested. It means being prepared for the kind of examination you are to take and for all possible questions. It means being rested and calm.

Some students prefer to review alone, while others prefer to study in groups. Small study groups of five or six students can be beneficial, since social learning tends to promote self-esteem and self-confidence. Groups should be a mixture of average and bright students in order for this to occur. Each student needs to discover that he or she is capable of selecting correct answers. Students should practice with diagnostic- and problem-type questions from this volume and from released National Boards. Each of the alternative answers should be discussed so that you understand *why* one answer is correct and others wrong.

Reprints of the most recently released National Boards are available through the American Student Dental Association (ASDA). These tests are distributed

in cooperation with the American Dental Association (ADA) Commission on National Dental Examinations, and may be ordered from

ASDA
211 East Chicago Avenue
Chicago, IL 60611

Review sessions should be frequent in order to reinforce learning, but not too long in duration. If you continue to study after mental fatigue has set in, you will be unable to recall what you have studied. You will be working against yourself. The mind functions best when it has adequate rest.

Types of Questions

You must be prepared for the types of questions included on the National Board Examinations. The Commission on National Dental Examinations has prepared a brief guide to indicate the types and form of objective questions which are presently being used in the examinations.^{4*}

COMPLETION. In one type of completion the problem or situation is posed in the stem of the item. The student, therefore, knows exactly what is being asked of him. The stem plus the correct answer makes a complete sentence.

1. The most frequent cause of failure of silver amalgam restorations is
 1. improper cavity preparation
 2. moisture contamination
 3. inferior alloy
 4. improper manipulation of the amalgam

In a second type of completion the stem may include several sentences, such as in a case study:

2. A tooth with a 3-month history of occasional severe pain began to ache steadily. The pain was worse when hot liquids were in the mouth. After extraction, the tooth was split open. The pulp chamber was completely filled with pus. A few remnants of pulp tissue were found in the apical end of the root canal. The condition described is
 1. acute partial pulpitis
 2. acute total pulpitis
 3. suppurative pulpitis
 4. strangulation of the pulp
 5. chronic total pulpitis

Another type of completion question has more than one correct answer.

3. The tension developed by a given muscle on its tendon is determined by

* Examples are taken from National Board Dental Examinations: Guide for the Construction of Test Items. Chicago, Commission on National Dental Examinations, ADA, July, 1976.

- a. the number of muscle fibers stimulated
 - b. whether or not the stimulus is supermaximal for all fibers
 - c. frequency of stimulation of each muscle fiber
 - d. the wave form of maximal stimulus
 - e. the prestimulation length of the muscle fibers
1. a
 2. a, b, and e
 3. a, c, and 3
 4. b and d
 5. c and d

QUESTION. As in the completion question the problem is posed in the stem. In this case the stem is a complete thought in the form of a question. The choices may be nouns, adjectives, adverbs, phrases, clauses, or sentences, but all are the same in any given item.

4. Which of the following substances is believed to be essential, in the process of repair, for the chemical transformation of procollagen to collagen fibers?
 1. Vitamin A
 2. Vitamin C
 3. Thromboplastin
 4. Cortisone
 5. Prothrombin
- Some questions will have more than one correct answer.
5. Which of the following cells or tissues have a good capacity for regeneration after injury or loss?
 - a. Collagenous fibrous tissue
 - b. Spinal cord
 - c. Epithelium of mucous membranes
 - d. Skeletal muscle
 - e. Renal glomeruli
 - f. Cardiac muscle
 1. a and b
 2. a, b, and c
 3. a and c
 4. a, c, e, and f
 5. c, d, and e

CAUSE AND EFFECT. The sentences in these items consist of a statement and a reason for that statement. The student must decide if

1. Both statement and reason are correct and related.
2. Both statement and reason are correct and *not* related.
3. The statement is correct but the reason is *not*.
4. The statement is *not* correct, but the reason is an accurate statement.
5. *Neither* statement nor reason is correct.
6. Penicillinase will reduce blood levels of penicillin *because* this enzyme renders penicillin inactive by competitive inhibition.
7. Atropine is used as premedication in general anesthesia with cyclopropane *because* atropine will block reflex bradycardia.

8. Epinephrine is contraindicated in patients during cyclopropane anesthesia *because* under cyclopropane epinephrine may precipitate ventricular arrhythmia.
9. A patient who responds to aspirin with severe dyspnea should be given an immediate subcutaneous injection of epinephrine *because* epinephrine relaxes the bronchiolar spasm.

The six types of items discussed have been approved by the Commission for use in the National Board Examinations. True-false items are no longer used, and negative items are discouraged. Since the National Board Examinations are written according to test construction norms, there are few grammatical clues to the correct answer, such as the articles a, an, and the.

Rest and Relaxation

As stated previously, being prepared also means being rested and calm. It does not pay to go without food, sleep, and recreation to cram for an examination. The student who crams pushes himself beyond the point of efficiency. The learner is "wasting time in the sense of getting less return for the investment of energy" (2).

Research has shown that a good night's sleep is essential to consolidate memories (6). Scientists have known for a long time that rapid eye movement (REM) during sleep indicates periods of dream sleep which serves crucial needs, and it appears that memory is one of those needs. The evidence indicates that the student who stays up all night cramming for a test is only introducing information that really cannot be learned, because the effort involved in staying awake prevents it. The next day none of the information can be recalled, and it will be of no use in the future because it has not been fully incorporated in the student's mind. On the other hand, the student who gets a good night's sleep is consolidating the material and making it a part of his or her long-term memory.

It is wise to relax deliberately just before the examination. Do not try to do a last minute review. All you can do with last minute reviewing is to confuse yourself with details. Rather, spend the few minutes before the examination in small talk or in reading a newspaper.

HOW TO TAKE THE NATIONAL BOARD DENTAL EXAMINATIONS

The important point in taking any examination is to have a definite plan in mind. People who know what to do and how they are going to do it seldom get upset or panicky.

The first step in beginning the examination is to read all directions carefully so that you will be able to answer in exactly the way specified. Directions such as

choose the “best” or “most closely related” indicate that all alternatives are plausible, but only one is correct.

Next divide the total number of questions in a section by the time allocated for them in order to judge how much time to spend on each question. Approximately 1 minute per question is allocated. It is the student’s advantage to utilize the full 3½ hours in each session. A student who finished the test quickly in a session probably did not analyze the questions carefully.

Approach each question by identifying the stated problem in the stem. It is very important that the stem and alternatives/distractors be accepted exactly as written, because each word was selected for a purpose. The meaning of each word must be precise, as defined in dental textbooks.

The examination is a straightforward test of your basic knowledge; the test items and alternative answers are not intended to trick you. Answer each question from the general principle rather than from the exception. You may have learned to respond to the exceptions on test items from your past experiences; however, this procedure is not appropriate for a test of basic knowledge like the National Board Examinations.

The test score is the total number of correct answers. Therefore it is usually best to go through the examination first, answering all the questions of which you are sure. In surveying the test, you might use a T to those questions which will require more time for answering, and a G to code those which may require guessing. Answer the “time” (T) questions the second time through the examination, and leave the “guessing” (G) questions until last.

Concentrate on one question at a time. This ability is sometimes called “bridge-player’s mentality”; it simply means ignoring the preceding and following questions unless the question at hand is a diagnostic interpretation question. The fact that “guessing” and “time” questions tend to linger in your mind and further reduce your concentration for the question at hand, is another reason why these should be coded and dealt with after you’ve answered questions that are easier for you.

You will probably be tempted to change some answers. If some answers are changed, be sure the first markings are completely erased. If you are uncertain between two answers, however, leave the answer you set down originally. Research has shown that when you are guessing, your first guess, based on careful reading, is likely to be your best guess.

HOW TO ATTACK OBJECTIVE QUESTIONS

You should determine a plan for dealing with those questions about which you are uncertain. Following

are some comments on how to attack objective questions (5):

1. **Read everything that is written and use it.** For example, suppose there are seven questions about Mrs. Doe. Preceding the first question is a brief personal, medical, dental, and social history of Mrs. Doe. Between questions 4 and 5 is a progress note in large type which reads, “Mrs. Doe improves. Oxygen therapy is discontinued.” The beginning of question 5 reads, “On the basis of the information provided about Mrs. Doe. . . .” In answering question 5, students should consider the information in Mrs. Doe’s history that precedes the first question, the information given in the stems of the four preceding questions, and the information in the progress note immediately preceding question 5, plus, of course, whatever else is included in the stem of question 5. In a sense this use of cumulative information in a patient-centered test situation is analogous to a real patient’s medical and dental histories, doctors’ orders, and medical and dental progress notes.
2. **Do not read into items what is not there.** Focus on the question or problem as it is stated in the stem. All of the options of an item may be correct or best for some situation or patient, but only one option is correct or best in terms of the specific question or problem posed in the item’s stem. If an item begins, “in general” or “as a rule,” the focus is on that which is generally true, correct, or best, not that which is only rarely the case.
3. **Pay attention to words in the stems that are underlined or capitalized.** The deliberate accenting of certain words in stems is part of the design of the items.
4. **Select the best answer of those provided, even though there may be another answer just as good which is not included.** Some students become confused when they do not see their favorite answer to a particular problem. Good test construction avoids the obvious, that is, it excludes correct answers that are so common as to be clichés. In addition, the person prepared for professional life must understand not only the main or primary factors involved in a problem but also the subordinate and contributing ones.
5. **Try to select the correct answer directly; if you cannot, try to determine the answer by eliminating the distractors.** When distractors are well constructed, the indirect route to the correct answer often requires more knowledge than the direct route, so the indirect method of selecting the correct answer to multiple choice test items is an acceptable practice.

6. **Do not add an “always,” “all,” or “every” which is not in the stem.** For example, “A great deal of bickering occurs among brothers and sisters.” This is true. Some students will mark it false, however, because their mental item read, “A great deal of bickering occurs among *all* brothers and sisters.” This is not the same question.

7. **Guard against omitting or dropping qualifying phrases such as “generally” or “to some extent.”** One way to prevent dropping a qualifying phrase is to underline “generally,” “not,” “sometimes,” “in part,” etc.

8. **Do not change the question by adding or deleting a qualifying phrase.**

9. **Be alert to double negatives.** “No one is always incorrect” does not mean “someone is always correct.”

10. **Do not change your answers.**

11. **There is no system in the listing of multiple choice answers.** Each statement must be answered on its own merit.

Guess intelligently since there is no penalty for guessing. If you can eliminate all but two alternatives, then it would be wise to flip a coin in order to obtain an unbiased choice between those two. If you knew the answer, there would be no choice to make; if you do not flip a coin, the chances are you will be snared by a word which surely introduces a bias. Flip the coin and give yourself a true 50–50 chance. If you are totally uninformed about the alternatives, randomly select one of the alternatives, making certain not to waste valuable time with such questions. You cannot pass the examination on guessing only, however. The probability of guessing 19 correct answers in a row, when given four choices, is 1 in 274,877,906,944 (Table 1–1).

A percentage of questions will fall into the category of the most difficult. When unable to answer these, do not be discouraged, but proceed with the test. No one is expected to get a perfect score. Your score will compare your performance with that of others taking the examinations.

HOW ARE NATIONAL BOARD EXAMINATIONS GRADED?

One point is given for each right answer. There is no penalty for guessing, so be sure to answer every question. The examinations are graded on a curve. The national average raw score is always equated with a standard score of 85. For example, if the national average raw score on a test were 60 points, *any student who answered 60 questions out of 100 correctly would receive a score of 85.* Without attempting to go into the statistics involved, two questions generally equal one standard point. In this example, when 60 right answers equal a score of 85, 40 right answers would equal a score of 75 [1].

Table 1–1. Probabilities for Guessing Successive Correct Answers from Four Choices

NO. OF CORRECT GUESSES	PROBABILITY*
1	$(1/4)^1 = 1/4$
2	$(1/4)^2 = 1/16$
3	$(1/4)^3 = 1/64$
4	$(1/4)^4 = 1/256$
5	$(1/4)^5 = 1/1,024$
6	$(1/4)^6 = 1/4,096$
7	$(1/4)^7 = 1/16,384$
8	$(1/4)^8 = 1/65,536$
9	$(1/4)^9 = 1/262,144$
10	$(1/4)^{10} = 1/1,048,576$
11	$(1/4)^{11} = 1/4,194,304$
12	$(1/4)^{12} = 1/16,777,216$
13	$(1/4)^{13} = 1/67,108,864$
14	$(1/4)^{14} = 1/268,435,456$
15	$(1/4)^{15} = 1/1,073,741,824$
16	$(1/4)^{16} = 1/4,294,967,296$
17	$(1/4)^{17} = 1/17,179,869,184$
18	$(1/4)^{18} = 1/68,719,476,736$
19	$(1/4)^{19} = 1/274,877,906,944$

* In general, the probability of guessing the correct answer from four choices n times in succession is $(1/4)^n$.

HOW MANY RIGHT ANSWERS DO YOU NEED TO PASS ANY ONE TEST?

This varies from year to year and from test to test. On Part I, if a test has 100 questions, about 40 right answers are required for a passing grade. (1)

You can see therefore why it is important to go straight through each test; you may know immediately if you have the minimum number correct.

SOME PERSONAL REMINDERS

Glasses worn for corrected vision will probably be more comfortable than contact lenses when testing extends over several hours.

When brain cells are utilized to make discriminating judgments on each question, energy is consumed which results in a feeling of fatigue upon completion of each section. The student who does not experience some degree of fatigue after taking an examination probably did not answer the written questions but read the questions to fit preset answers. The chances are this student “blew” the test.

You should develop a disciplined diet control regimen which insures a high protein intake for sustained energy release during the examinations. Adequate sleep is essential for maximum organization of ideas and recall of facts. A few minutes deep relaxation between exams will help allay synaptic fatigue. It is not advisable to take drugs since these may impede your performance.

Each candidate is responsible for protecting the integrity of his answers. If cheating is noted during the examination or evidence of cheating is disclosed by the computer during processing, candidates involved, whether they be copiers or those copied from, will be failed and there will be a minimum waiting period of one year before the candidate can re-apply [3].

It is sincerely hoped that this volume will help you in preparing for the National Board Dental Examinations. But remember, there is no substitute for knowledge.

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ANSWER KEY

- | | | |
|------|------|------|
| 1. 1 | 4. 2 | 7. 1 |
| 2. 3 | 5. 3 | 8. 1 |
| 3. 3 | 6. 3 | 9. 1 |

2

GROSS AND NEUROANATOMY

Alexander H. Martin

This chapter provides both the student and the practicing dentist with an overview of the gross morphology of the body. It is intended to provide 1) an opportunity to acquire and use correct anatomic terminology, 2) a review of the gross morphology and organization of the organs and tissues of the body, and 3) a detailed examination of the head and neck region of the body.

TERMINOLOGY

In all descriptive accounts, written or oral, when reference is made to relationships, the body must be considered to be in the "anatomic position." The body is erect, feet flat on the floor, the palms of the hands facing anteriorly, and the eyes looking straight ahead.

Relationships

Anterior, ventral or (front): nearer the anterior surface of the body, e.g., the jaw is anterior to the vertebral column

Posterior, dorsal or (back): nearer the posterior surface of the body, e.g., the vertebral column is posterior to the sternum

Superior, cephalic, or rostral: towards the head or upper part of the body, e.g., the skull is superior to the rib cage

Inferior or caudal: nearer the lower part of the body, e.g., the wrist is inferior to the shoulder

Medial: nearer the midline of the body, e.g., the sternum is medial to the scapula

Lateral: further from the midline, e.g., the ears are lateral to the nose

Superficial: nearer the surface of the body, e.g., the breast lies superficial to the rib cage

Deep: further away from the skin surface, e.g., the heart lies deep to the sternum and ribs

Two other terms relate only to the limbs:

Proximal: closer to the trunk, e.g., the shoulder is proximal to the elbow

Distal: further from the trunk, e.g., the hand is distal to the arm

Planes of the Body

The body, or any part, may be divided along certain planes:

Median or midsagittal: an anteroposterior (A-P) plane that is vertical to the ground and divides the body into equal right and left halves

Sagittal: any anteroposterior plane parallel to the median plane

Coronal or frontal: a vertical plane at right angles to the sagittal, dividing the body into anterior and posterior parts

Transverse, horizontal, or cross: any plane parallel to the ground and at right angles to the sagittal or coronal

Movements at Joints

To flex: to bend or make an angle

To extend: to stretch out or to straighten

To abduct: to draw away from the median plane of the body

To adduct: to move towards the midline

To circumduct: to perform the above four motions in sequence

To rotate: to turn around a long axis, as the arm at the shoulder joint

To pronate: to turn the hand so that the palm of the hand faces posteriorly

To supinate: to turn the palm of the hand back to the anatomic position

To protract, retract, elevate, or depress: to pull anteriorly, posteriorly, superiorly, or inferiorly, respectively. Both the mandible and shoulder girdle can be moved in these directions.

SKELETAL SYSTEM

The skeleton is normally composed of 206 bones and associated cartilages, which together provide the framework of the body. The skeleton can be subdivided into two parts: 1) the axial, composed of the skull and vertebral column with associated hyoid, ribs, and sternum; and 2) the appendicular, composed of the limbs and limb girdles. Skeletal functions include providing attachment for muscles, protecting vital organs, supporting soft tissue, storing minerals such as calcium and phosphate, and serving as a hematopoietic organ to form red blood marrow.

Bones are grouped according to their geometric shape, for example, the humerus is a long bone, the carpals are short bones, the parietal is a flat bone, and the vertebrae are irregular bones. There are also pneumatic or air-filled bones, i.e., the maxilla and frontal, and sesamoid or seedlike bones, which are found embedded in tendons, i.e., the patella.

Bones also may be classified on the basis of development. At approximately the 6th–8th week of fetal life, fibrous or cellular mesenchymal condensations appear at the site of future bone. Ossification of the fibrous tissue results in intramembranous bone formation, which starts in the center(s) and radiates towards the periphery. The peripheral connective tissue forms the fibrous periosteum. Endochondral ossification forms cartilaginous bones. The mesenchymal condensation is followed by a cartilaginous model that grows by apposition from the periosteum and by cell multiplication at the extremities.

Prior to birth in the human, a second phase in the ossification of cartilaginous bones takes place. In the cartilaginous ends, and at the margins and processes of irregular bones, secondary ossification centers appear. During the growing phase a narrow strip of cartilage remains between the shaft and the ends of long bones. This strip is known as the epiphyseal cartilage, or plate, and is necessary for bone growth. There is no growth of bone tissue *per se*; bone grows by the apposition of newly formed bone on free surfaces. The continuous deposition and resorption of bone permits readjustment of its form.

Another phenomenon, the relative amount of growth at proximal and distal epiphyses of a long bone must be considered when examining bone growth. The proximal and distal epiphyses contribute unequally to the total increase in length. The end where a secondary center first appears is the last to fuse; therefore, this end contributes the most to total growth of the bone. In the upper limb, the secondary centers appear first in the proximal end of the humerus and the distal ends of the radius and ulna. Growth therefore continues longest at the shoulder and wrist. In the lower limb, secondary centers first appear in the distal end of the femur and

the proximal end of the tibia so that growth continues longest at the knee. In the event of injury or disease, the ultimate degree of limb shortening depends upon which epiphysis is affected.

A long bone consists of a diaphysis, or shaft, in the middle and an epiphysis, or extremity, at each end. The wider part of the shaft, adjacent to the epiphyseal plate, is called the metaphysis. Following cessation of growth, the shaft and extremities appear as a single continuous bone. Long bones have an outer compact and inner spongy layer, which surround a medullary (marrow) cavity containing red or yellow marrow. Periosteum surrounds each bone, except for the articular portion, and becomes continuous with the articular capsule around joints. The periosteum participates in the process of bone growth and also serves for the attachment of muscles and ligaments.

Bones have characteristics such as prominences, pits, tubercles, fossae, and sinuses, to mention a few, which serve as landmarks in physical diagnosis and radiology.

Blood supply to bone is abundant. Particularly important are the vessels supplying the epiphysis and metaphysis, which are separated by the epiphyseal plate during growth. Because the plate receives blood from both epiphyseal and metaphyseal sources, vascular disturbance in either area can cause major disturbance in growth. Nutrient canals and orifices contain blood vessels that supply and drain the bones. Nutrient canals in long bones are usually directed away from the growing extremity of the bone.

Axial Skeleton

The skull may be considered a box that surrounds and protects the brain, to which are attached various facial and jaw bones as well as scalp and facial muscles. The vault of the skull arises by intramembranous ossification, while the base arises by endochondral ossification. At birth, appreciable areas of the margins of the cranial vault are still membranous and are called fontanelles.

The superior aspect of the skull, corresponding to the calvarium, is formed by the frontal, two parietals, and the occipital bones. These are joined by sutures: sagittal, coronal and lambdoid. The highest point of the skull is called the vertex. The posterior aspect of the sagittal suture is flanked by orifices in the parietal bone for the passage of emissary veins. These passages allow flow between superficial veins of the scalp and the intracranial venous sinuses.

The posterior aspect of the skull is formed by the parietal, temporal, and occipital bones and contains the posterior part of the sagittal, as well as the lambdoid and occipitomastoid sutures. The sagittal and lambdoid sutures meet at the lambda. The center of the external occipital protuberance is called the inion. The superior

Table 2-1. Foramina and Processes of Inferior Aspect of Skull

STRUCTURE	LOCATION	IMPORTANCE
Foramen magnum	Occipital bone	Passage of spinal cord, meninges, vertebral artery, ascending rootlets of XI cranial nerve, anterior and posterior spinal arteries, and ligaments between occipital bone and axis
Occipital condyles	Occipital bone	Articulation with 1st cervical vertebrae
Condylar canal	Occipital bone	Emissary vein (from suboccipital to inferior end of sigmoid sinus)
Hypoglossal canal	Occipital bone	Hypoglossal nerve (XII); meningeal branch of ascending pharyngeal artery from external carotid
Jugular foramen	Temporal and occipital bones	Internal jugular vein; meningeal arteries from occipital and ascending pharyngeal; IX, X, and XI cranial nerves; and inferior petrosal sinus
Styloid process	Temporal	Attachment of stylohyoid muscles and ligaments
Stylomastoid foramen	Temporal	Facial nerve
Mastoid process	Temporal	Attachment of sternocleidomastoid muscles and location of mastoid air cells
Carotid canal	Temporal	Internal carotid artery; sympathetic nerve fibers (carotid plexus)
Foramen lacerum	Between temporal, sphenoid, and occipital	Covered in life by cartilage.
Foramen ovale	Sphenoid	Mandibular nerve (V ³); accessory meningeal artery
Foramen spinosum	Sphenoid	Middle meningeal artery; meningeal branch of V ³
Pterygoid canal	Sphenoid	Greater petrosal nerve from facial; sympathetic fibers from carotid plexus.

and inferior nuchal lines on either side indicate muscle attachments. The superior nuchal line also indicates the cephalic limit of the cervical region. The right and left mastoid foramina, which transmit emissary veins, are found near the occipitomastoid suture.

The lateral aspect of the skull contains both a cranial and a facial portion. The cranial portion consists of the frontal, parietal, and temporal bones, as well as the temporal and infratemporal fossae. The junction of the frontal, parietal, temporal, and greater wing of the sphenoid is called the pterion, a clinically important point since it indicates the location of the anterior branch of the middle meningeal artery.

The zygomatic arch extends anteriorly from the external auditory meatus to the zygomatic bone. Anteroinferior to the meatus is the temporomandibular joint, while posteriorly lies the mastoid process. This process, which gives attachment to muscles, protects the exit of the facial nerve. Since the mastoid process is not present in the newborn, the facial nerve can be injured during delivery, especially when forceps are involved.

The temporal fossa contains the temporal muscles. The infratemporal fossa contains the inferior portion of the temporal muscle, the pterygoids, plus the vessels and nerves supplying the region. The fossa is bounded anteriorly by the maxilla, medially by the lateral pterygoid plate of the sphenoid, laterally by the mandible, and posteriorly by the mastoid process.

The anterior aspect of the skull also has both a cranial and facial portion. The frontal bones, forming the forehead, intersect on a line which, if it persists, is called the metopic suture.

The bony orbits present four margins: the superior with the supraorbital notch or foramen is formed by the frontal; the lateral, by the zygomatic; the inferior, by the maxilla; and the medial, by the maxilla, lacrimal,

and frontal bones. The remainder of the face contains the prominence of the cheek, the nasal apertures, and upper and lower jaws.

The inferior aspect of the skull, with mandible removed, is formed by several bones and is characterized by foramina and processes through which nerves and vessels exit and to which muscles attach. From posterior to anterior the most important are listed in Table 2-1.

The hyoid bone, located anteriorly in the neck between mandible and larynx, lies at the level of the third cervical vertebra. This bone is connected to, and held in place by, the stylohyoid ligaments. The hyoid is divided into a median body and two pairs of horns, the greater and lesser cornua.

VERTEBRAL COLUMN. The functions of the vertebral column are to support the trunk, to transfer weight to the pelvis and the lower limbs, and to protect the spinal cord. The column is formed by several bones that increase in size from above downwards. They can be divided into groups that have their own characteristics. Thus there are from rostral to caudal: 7 cervical, 12 thoracic, 5 lumbar, 5 sacral, and usually 4 coccygeal vertebrae. Most of the vertebrae are joined together by fibrocartilage disks that allow a limited amount of movement between any two bones but a considerable amount of movement in the column as a whole.

The vertebral column is not straight. In the adult there are four pronounced curves or flexures. These are convex forward in the cervical and lumbar regions, and concave forward in the thoracic and sacral regions.

The rib-bearing vertebrae are said to represent "typical" vertebrae, while the other groups represent "modified" thoracic vertebrae.

Thoracic Vertebrae. Located anteriorly in a thoracic vertebra is a rounded body, or centrum, which is

weight bearing. Located posteriorly is the vertebral arch enclosing the vertebral foramen, through which passes the spinal cord. Each vertebral arch has two transverse processes projecting posterolaterally and a spinous process posteriorly. These processes are important for the attachment of muscles and ligaments.

The part of the vertebral arch between the body and the transverse process is termed the pedicle; that between the transverse and spinous process is termed the lamina. Superior and inferior to the bases of the transverse processes are the superior and inferior articular processes. Superior and inferior to each pedicle are the superior and inferior vertebral notches, respectively. In the articulated skeleton the inferior notch of one vertebra, together with the superior notch of the vertebra below, form the intervertebral foramen, through which passes a spinal nerve.

The movements that occur between thoracic vertebrae are mainly lateral flexion and rotation. Flexion and extension occur only to a small extent.

The ribs articulate with smooth articular facets at the ends of the transverse processes of the upper ten thoracic vertebrae. The ribs also articulate with the bodies of the thoracic vertebrae and, depending on their position in the column, the vertebral bodies have either one or two articular facets on their lateral aspects.

Cervical Vertebrae. Only the third to sixth cervical vertebrae are regarded as "typical" cervical vertebrae. The first and second vertebrae are modified in connection with movements of the head, while the seventh resembles a thoracic vertebra.

Compared with a thoracic vertebra, the body of a typical cervical vertebra is smaller and more oval. The vertebral foramen is large and almost triangular in shape. The transverse processes are shorter, and each contains a conspicuous foramen, the foramen transversus, which transmits vertebral vessels. At the extremity of each transverse process is an anterior and a posterior tubercle separated by a sulcus along which passes the anterior primary ramus of a spinal nerve.

The spinous process is short and is usually bifid at its extremity. The superior and inferior articular facets, at the bases of the transverse processes, are more horizontal than those of a thoracic vertebra.

Movements which occur between typical cervical vertebrae are flexion, extension, and lateral flexion. Rotation occurs only to a slight extent.

Compared with the typical cervical vertebra, the seventh has a larger, rounder body, a long bifid spine, and usually, a smaller foramen transversarium.

The atlas, or first cervical vertebra, has no body. It consists of an anterior arch which replaces the body, a posterior arch that is equivalent to the vertebral arch, and, on either side, a lateral mass with a small trans-

verse process. The latter contains a foramen transversus.

The lateral masses possess large, concave superior articular facets for articulation with the occipital condyles of the skull. The smaller, flatter inferior facets articulate with the superior facets of the second cervical vertebra, the axis.

A small anterior tubercle projects from the front of the anterior arch of the atlas, and a small posterior tubercle, representing the spinous process, projects from the back of the posterior arch. On the posterior aspect of the anterior arch is an articular facet for the dens of the axis. On each side of the superior surface of the posterior arch is a broad groove along which the vertebral artery passes before entering the skull.

The axis is characterized by an upward projection from the body, termed the dens. It represents the body of the atlas, which has been fused to the axis. Because the dens articulates with the facet on the anterior arch of the atlas, it acts as a pivot around which the atlas can rotate.

The superior articular processes at the bases of the transverse processes are more horizontal and further forward than the inferior processes so that the C2 spinal nerves emerging between atlas and axis pass posterior to the articular processes, whereas the C3 spinal nerves emerging between the axis and the third cervical vertebra pass anterior to the articular processes.

Lumbar Vertebrae. Larger than the thoracic vertebrae, lumbar vertebrae bear more weight. The body of a lumbar vertebra is large and kidney-shaped. The transverse processes are slender, and small accessory processes project from their posterior aspects. The articular processes are almost vertical. When viewed from the lateral side, the spinous processes appear deep. The vertebral foramina are large enough to accommodate the cauda equina, a lash of nerves replacing the spinal cord, below the level of the second lumbar vertebra.

The movements occurring between the lumbar vertebrae are flexion, extension, and lateral flexion with some rotation.

Sacral Vertebrae. The sacrum consists usually of five fused bones, decreasing in size from above downwards, which form the posterior wall of the pelvis. The sacrum is situated between the two hip bones and articulates with them at two large articular surfaces on the lateral aspects of the first to third sacral vertebrae. Since the sacral vertebrae are fused, no movement takes place between them. Viewed from above, the first sacral vertebra is seen to consist of a large body with two lateral masses of alae (wings). The alae are formed by the pedicles and transverse processes. The superior articular processes have vertical articular surfaces. The vertebral foramen is distinctly triangular.

From the anterior aspect, the lines of fusion between the sacral vertebrae are evident, as are the large intervertebral foramina for the anterior primary rami of the sacral spinal nerves.

From the posterior aspect, the short spinous processes are visible, together with the foramina for the posterior primary rami of the sacral spinal nerves.

The vertebral foramen ends at the level of the fourth or fifth sacral vertebra.

Coccygeal Vertebrae. The coccyx consists usually of four bones which, like the sacral vertebrae, decrease in size from above downwards. The bones may be fused with each other and with the sacrum.

The first coccygeal vertebra possesses rudiments of transverse processes but this is about its only resemblance to the rest of the vertebral column.

RIBS. There are 12 pairs of ribs, one pair for each thoracic vertebra. The upper ten pairs join to the sternum via costal cartilages, but the lowest two pairs do not reach the sternum. The vertebral end of most ribs consists of an enlarged head with an articular surface which attaches to the vertebral body. From the head, the neck extends laterally to a posterior projection, the tubercle. This too has an articular surface which attaches to the transverse process of the vertebra. From the tubercle the shaft curves forward, inferiorly and laterally, then superiorly and medially where it ends abruptly. Here the rib attaches to a costal cartilage. Just beyond the tubercle the rib curves sharply; this is the angle of the rib. On the inner surface of the underside of the rib is a groove, the costal groove, in which run the intercostal nerve and vessels.

The first rib differs from the others in that it is short, flat, and broad and is set at a different angle from the other ribs. There is no angle and no costal groove. The upper surface is marked by the attachment of the scalene muscles of the neck and grooved by the subclavian vessels and nerves.

The 11th rib is short, has no tubercle, i.e., does not articulate with the transverse process of the 11th thoracic vertebra, and has only a trace of a costal groove. The anterior end, which is pointed, is embedded in the abdominal wall.

The 12th rib is essentially the same as the 11th but has no angle and no costal groove. It can vary in length between 2.5 and 20 cm.

STERNUM. The sternum is a long, flat bone which is formed from fused segments. It forms part of the anterior chest wall. Costal cartilages attach the upper ten pairs of ribs to its sides. It consists of the manubrium, the body, and the xiphoid process. The upper part, the manubrium, joins the body at an angle, the angle of

Louis or manubriosternal angle. The manubrium may or may not be fused to the body.

The body consists of four fused segments, or sternbrae, and the points of fusion are often visible. The lowest part of the sternum is the xiphoid process. This is often cartilaginous, palpable, and movable. The first costal cartilage on each side attaches to the side of the manubrium. The second attaches to the sternum at the sternal angle. The third to sixth join the body of the sternum. The seventh attaches to the junction of the body and xiphoid process. The costal cartilages of the eighth to tenth ribs join together and attach to the xiphoid process with the seventh.

The upper surface of the manubrium has an oblique articular facet at each end for the attachment of the clavicles and a midline depression called the jugular notch.

Appendicular Skeleton

When man stood upright, the lower limbs took over the responsibility of bearing weight and locomotion, thus freeing the upper limbs to perform other functions such as prehension. These differences in function are reflected in differences between the skeletons of the upper and lower limbs.

THE UPPER LIMB. The upper limb may be divided into four regions with their attendant skeletal parts: 1) shoulder or pectoral girdle, scapula and clavicle; 2) arm, humerus; 3) forearm, radius and ulna; and 4) hand, carpals, metacarpals, and phalanges.

Scapula and Clavicle. The scapula is a triangular bone having two surfaces and three borders. The anterior or costal surface lies against the ribs. The dorsal or posterior surface has a prominent transverse spine which projects laterally into a free process, the acromion. The tip of the acromion articulates with the lateral end of the clavicle. The medial border lies closest to the vertebral column. The lateral border meets the medial inferiorly, at the inferior angle of the scapula, and passes up toward the axilla. The superior border joins the upper end of the medial border at the superior angle of the scapula. At the point where the superior and lateral borders would normally meet is the glenoid fossa, with which the humerus articulates.

Along the superior border is a pronounced scapular notch. If crossed by the transverse scapular ligament the notch is converted into a foramen. The suprascapular nerve and vessels pass below or above the ligament respectively. Laterally, the superior border is extended into an anteriorly curved projection, the coracoid process.

The clavicle is an elongated curved bone which at-