Introduction

Anatomic Imaging

Anatomic imaging began at the turn of the century with Roentgen's discovery of x-rays in 1896. Since that time, medical imaging has evolved into computerized systems that allow scientist and physicians to look inside the body with amazing accuracy and without the trauma and risk of explanatory surgery. Many of the advances in medical diagnosis and treatment are only possible because of anatomic imaging. A list of modern imaging techniques includes traditional x-rays, computer tomography (CT), magnetic resonance imaging (MRI), dynamic spatial reconstruction (DSR), digital subtraction angiography (DSA), positron emission tomography (PET), optical coherent tomography (OCT), echo-planar MRI (EPI), and ultrasound.

Typically, the views of the body produced by these technologies are presented as transverse, sagittal, or frontal sections. Sagittal and frontal sections are usually less difficult to understand because most anatomy textbooks primarily use sagittal and frontal views to illustrate anatomy. However, most CT and MRI images are presented as transverse sections, which is why understanding cross-sectional anatomy is important. This miniatlas is designed to help students acquire a basic knowledge of cross-sectional anatomy that will not only be useful, but will also make their careers more interesting and meaningful. However, before explaining how to use the miniatlas, some background information on CT and MRI is appropriate.

Computerized Tomography

Computerized tomography (CT) literally means to cut or section (Gr. *tomos*) the body and use the computer to write (Gr. *grapho*) a picture of the section. In computerized tomography, the patient is placed into a scanner and is exposed to a narrowly focused x-ray beam (Figure 1). Radiation that is not absorbed by the patient's body is called **remnant radiation**. The remnant radiation passes through the patient's body and is measured by a series of detectors that send the data to a computer. The data is converted into picture elements called **pixels** (picture x elements), which are the tiny boxes of varying colors that make up a digital picture. In a process called **image reconstruction**, the computer combines

FIGURE 1 CT SCANNER The patient lies on the cot, which automatically moves through the gantry opening. The circular gantry can produce x-rays that pass through the patient's body from every angle to be detected by sensors within the gantry.

the pixels to form an image. Each image is like a single slice from a loaf of bread. After each image is made, the patient is moved slightly and another image is taken, producing additional slices through the body.

On the average, it takes over 262,000 pixels to form a single CT image, which is like a complex mosaic formed by arranging and connecting together small pieces of glass or stone. The computer can arrange the pixels to form transverse, sagittal, or frontal images of the body.

The amount of radiation absorbed by different tissues determines the appearance of the tissues in CT images. The denser the tissue, the greater is the amount of radiation absorbed by the tissue. Consequently, less remnant radiation passes through denser tissues than through less dense tissues. The computer uses the amount of remnant radiation that is detected by the sensors as a basis for coloring the tissues. Dense tissues, such as bone, appear white. Air, which is not dense compared to tissues, is easily penetrated by x-rays and appears black. Thus, air-filled structures, such as the lungs, appear black. Fat, muscle, and organs that fall between the densities of bone and air appear as varying shades of gray (Table 1).

In order to better see certain hollow organs, such as blood vessels, a contrast medium can be placed in the organ. A **contrast medium** is a dense liquid that prevents the passage of remnant radiation and appears white in a CT image (see Table 1). The size and shape of hollow organs can be determined in CT images because a liquid contrast medium assumes the shape of the organs it is contained within. For example, iodinated contrast medium is injected into blood vessels, the urinary bladder, or ureters, and barium sulfate is given orally or rectally to enhance the gastrointestinal tract.

The newest generation of CT scanners are

TABLE 1 APPEARANCE OF DIFFERENT TISSUES IN CT AND MRI IMAGES

Tissue	CT Image	T_1 MRI Image	T_2 MRI Images
Bone	White	Black	Black
Muscle	Gray	Gray	Dark gray
Brain			
White matter	Dark gray	Gray	Dark gray
Gray matter	Gray	Dark gray	Gray
Fat	Dark gray to black	White	Gray
Cerebrospinal fluid (CSF)	Black	Black	White
Blood			
Flowing	White*	Black	Black
Nonflowing	White*	Gray	White
Contrast media	White	White	Not used
Air-filled structures such as the lungs, stomach, and colon	Black	Black	Black

*Only if iodinated contrast media is present; otherwise appears gray.

able to produce an image so fast that physiological motions, such as respiratory or cardiac movements, do not blur the image. For this reason, CT is used for studies of the chest, abdomen, pelvis, and soft tissues of the neck.

Magnetic Resonance Imaging

To make a **magnetic resonance image (MRI)**, the patient is placed into a scanner that produces a very powerful magnetic field, which affects the nuclei of the atoms in the patient's body. Many atomic nuclei, including the protons that form the nuclei of hydrogen atoms, rotate or spin about, much like tiny tops or gyroscopes. Because a moving charge creates a magnetic field around itself, the hydrogen protons are like little bar magnets. Normally, the "axes" of the hydrogen proton "magnets" are oriented in many different directions. The magnetic field produced by the scanner causes the hydrogen protons in the patient's body to align in the same direction, in much the same way that the needle of a compass aligns with the magnetic north pole.

After the protons are aligned, a **radiofrequency (RF) pulse** is used to establish a second magnetic field that is typically at a ninety degree angle to the first magnetic field. The second magnetic field causes the hydrogen protons to "tip over" in relation to the first magnetic field. The energy in the RF pulse also raises the energy level of the hydrogen protons. When the RF signal is turned off, the hydrogen protons are said to **relax**, which means they realign with the first magnetic field. As they relax, the hydrogen protons release the energy acquired from the RF pulse and return to their previous lower energy level by giving off energy that can be detected by sensors in the scanner. As with CT technology, the data collected by the sensors is used to form pixels, and through image reconstruction, the computer can form transverse, sagittal, or frontal sections of the patient's body.

The process just described is called magnetic resonance imaging because it requires magnetic fields and the resonance of the hydrogen protons. To use an analogy, each hydrogen proton is like a tuning fork. When energy is applied to a tuning fork by striking the tuning fork, it releases the energy by producing sound waves. If many tuning forks that can produce the same sound waves are struck at the same time, then they all vibrate together at the same sound frequency and are said to be in resonance. When the RF pulse is applied to the hydrogen protons, they are all excited to the same higher energy level and are in resonance.

When the RF pulse ends, the hydrogen protons release an energy signal as they realign with the first magnetic field. The time required for the excited hydrogen protons to realign with the first magnetic field is called the **relaxation time**. The return to the unexcited state exhibits two relaxation times called T_1 and T_2. The energy signal released from the hydrogen protons during the first second is T_1, and the signal after one second is T_2. The signals received by the computer for T_1 and T_2 are used to create different shades of gray for different types of tissues (see Table 1).

Magnetic resonance imaging detects the presence of hydrogen protons, and not other atoms, because the RF pulse used causes the resonance of only hydrogen protons. The nuclei of other atoms have different resonance frequencies, much like different tuning forks produced different sounds. The use of hydrogen protons in MRI is not by accident. Over 75 percent of the human body is water and each water molecule contains two hydrogen protons. In addition, many organic molecules such as carbohydrates, lipids, and proteins contain abundant hydrogen. The number of hydrogen protons in a tissue, and the relationship of the hydrogen protons to surrounding atoms, determines the different energy signals recorded for different tissues when the hydrogen protons relax.

General Features of the Miniatlas

The miniatlas consists of 25 photographs of transverse sections through a cadaver. The number of sections has been kept to the minimum necessary to show major anatomical features. The level of each section is indicated in a level orientation figure, and a numbered key is used to identify structures on each photograph. A systemic description of the features of each cadaver section is also provided. In addition, there are CT and MRI pictures that match as closely as possible the cadaver sections. Any structures seen in a CT or MRI, but not seen in a cadaver section, are briefly described. At the end of the atlas there are CT and MRI pictures that illustrate the use of these technologies for detecting pathologies.

How to Use The Miniatlas

In typical undergraduate anatomy courses, the body is studied from a systemic approach. A **system** is a group of structures that have one or more common functions. Examples are the digestive, circulatory, nervous, respiratory, and skeletal systems.

Most cross-sectional anatomy atlases assume that the reader already knows the parts of each system, and understands the three-dimensional relationship of the parts within a system to each other. Therefore, when a section is made through the body, the emphasis is on the relationship between the parts of different systems within that particular section. However, without an understanding of the systems, this approach is quite confusing to beginning students.

This miniatlas of human cross-sectional anatomy is designed to be used at the same time that the systems are being learned. The parts of each system are described by system in a *Systemic Descriptions* section. Thus, it is possible to concentrate on one system at a time. Furthermore, the parts of a system seen at one level are related to the parts seen in sections at other levels. For example, starting with a section through the oral cavity, the systemic description section describes the parts of the digestive system seen at this level, such as the tongue and the parotid salivary glands. In succeeding sections, the systemic description for the digestive system describes the new structures encountered and their relationship to other sections. Thus, the oral cavity joins the pharynx (throat), which is connected by the esophagus to the stomach.

In order to effectively present a systemic approach, more than a verbal description is needed. High quality photographs and illustrations of each system from a sagittal or frontal view are also required, because they show the superior to inferior relationships between the parts of a system. To assist with understanding head and neck anatomy, a sagittal and frontal view of the head and neck are presented on pages 6 and 7 of this introduction. Additional illustrations and photographs are provided in the third edition of Anatomy and Physiology by Seeley, Stephens, and Tate (SST).

The recommended procedure for using the miniatlas is to read and understand the anatomy of a system using an introductory anatomy and physiology text. In the systemic descriptions in the miniatlas, the parts of a system are followed by numbers, which indicate the location of the parts on the cadaver section. In addition, it may be useful to refer to an introductory anatomy and physiology text to see the structures from a frontal or sagittal view. For example, Figure 2 refers to a sagittal view of the brain in Anatomy and Physiology by Seeley, Stephens, and Tate.

Next, relate what is seen in the frontal or sagittal view to what is seen in the transverse cadaver section. The approximate location of the cut on the frontal or sagittal section can be determined by using the level orientation diagram provided for each section and by noting what parts are cut in the cadaver section. For example, the orientation diagram for Section 1 indicates a cut through the superior part of the braincase, and the systemic description for the nervous system describes a cut through the cerebrum, corpus callosum, and lateral ventricles. The location of the cut is shown as a black line in Figure 2.

A ruler was used to draw the location of the cut on the illustration. You may want to straighten out a paper clip and lay it on the illustration at the location of the cut. Thoughtful consideration of the cross-sections in the miniatlas and the illustrations in the textbook will result in a three-dimensional understanding of each system.

Although this atlas can be used to study only one system at a time, as you study a particular system you probably will note some features of the other systems. For example, you probably will already have studied the skeletal system before you study the nervous system. Examine the cross-sections and identify the bones and parts of bones because they are easily seen. Then, as you study additional systems, use the bones as "landmarks" to guide you through the sections. In addition, begin to relate the parts of one system to another. For example, while studying the digestive system you might note that the esophagus is posterior to the trachea and anterior to the descending aorta.

After you understand a system on the cadaver sections, take some time to examine the CT and MRI images. These technologies produce amazingly good pictures of the inside of the body, and with your new knowledge of cross-sectional anatomy, you will be able to identify the major parts of the body. Also examine the CT and MRI sections at the end of the atlas to discover how they can reveal pathologies within the human body.

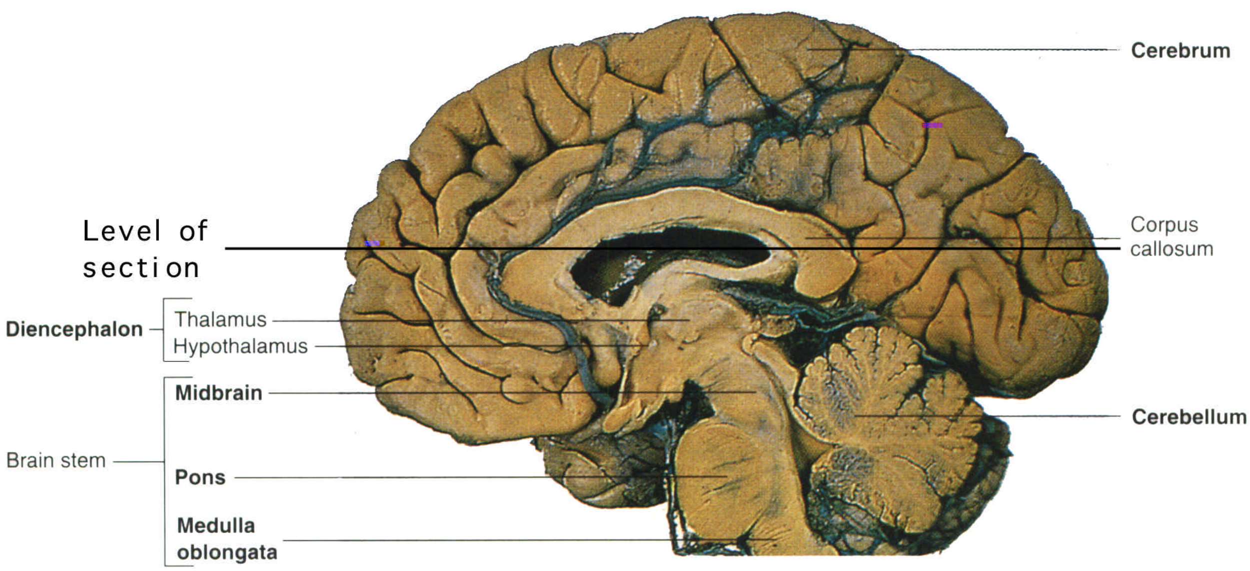

FIGURE 2 SAGITTAL VIEW OF THE BRAIN Taken frm Anatomy and Physiology by Seeley, Stephens, and Tate. The black line indicates the level of Cadaver Section 1.

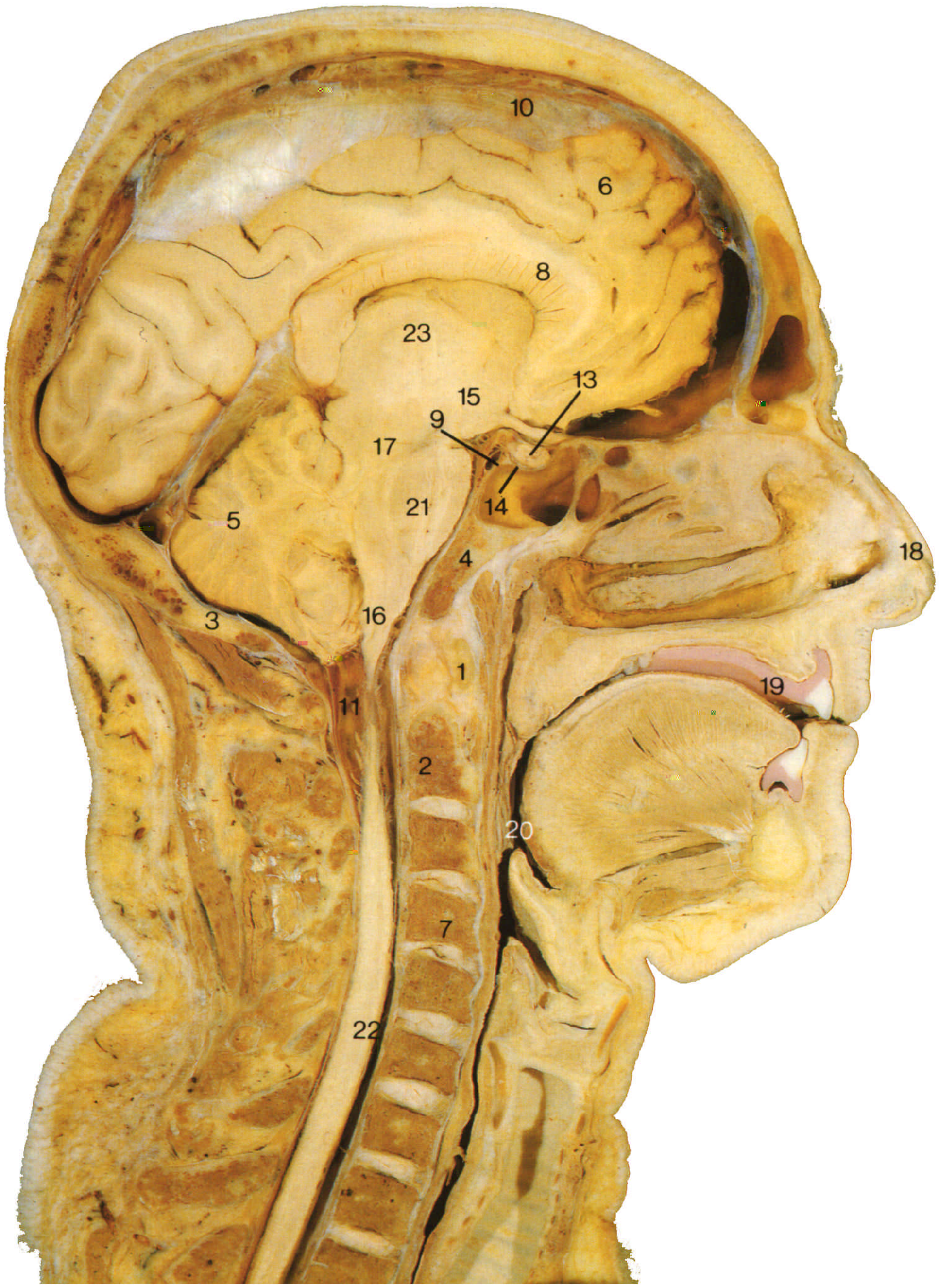

FIGURE 3 SAGITTAL SECTION OF THE HEAD Reprinted with permission from England, M.A. and Wakely, J. 1991. Color Atlas of the Brain and Spinal Cord.

1. Atlas
2. Axis
3. Base of occipital bone
4. Body of sphenoid bone
5. Cerebellum
6. Left cerebral hemisphere
7. Cervical vertebrae
8. Corpus callosum
9. Posterior ridge of the sella turcica
10. Falx cerebri
11. Foramen magnum
12. Fourth ventricle
13. Pituitary gland
14. Sella turcica
15. Hypothalamus
16. Medulla oblongata
17. Midbrain
18. Nose
19. Oral cavity
20. Oropharynx
21. Pons
22. Spinal cord
23. Thalamus

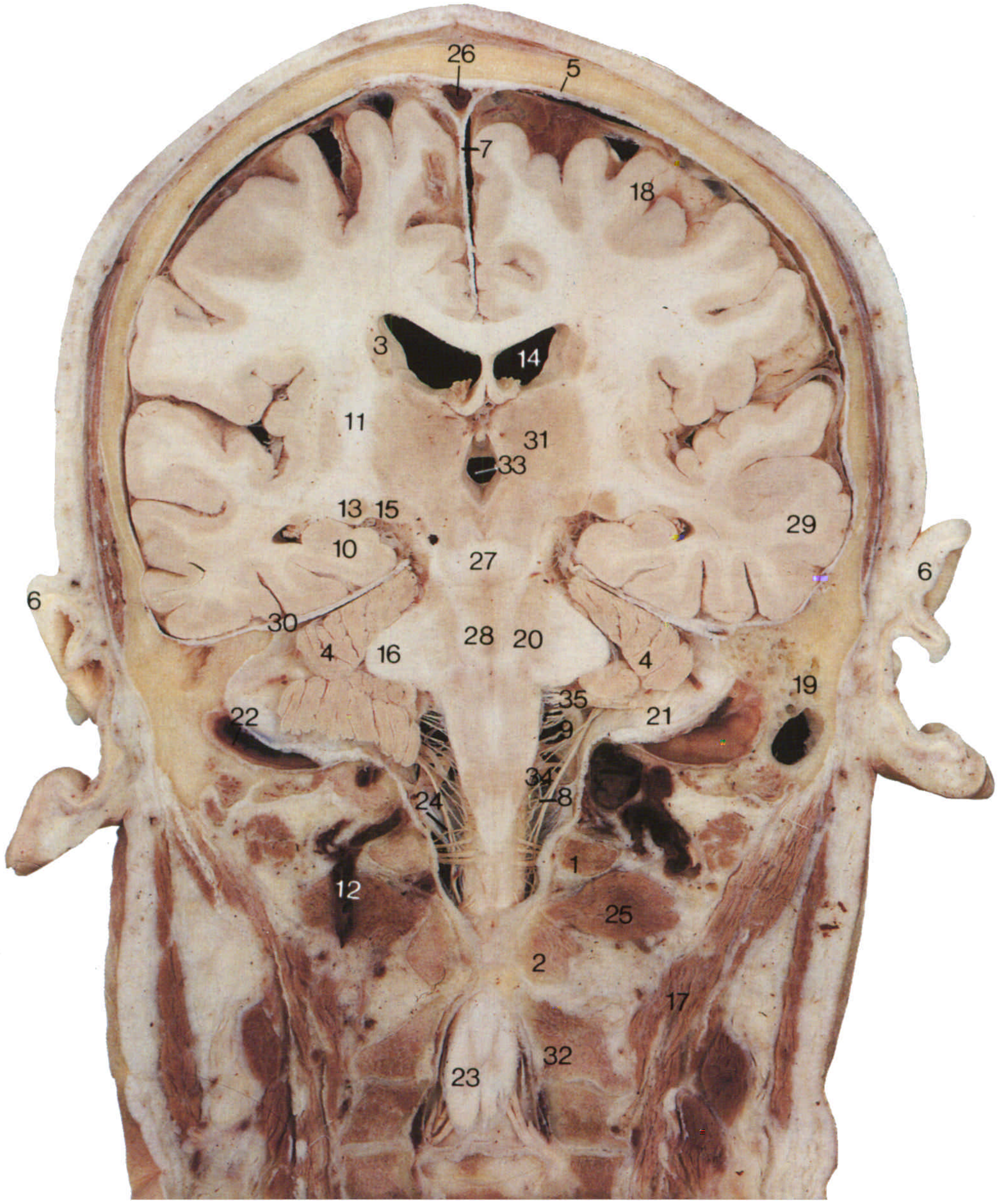

FIGURE 4 FRONTAL SECTION OF THE HEAD AND NECK Posterior view showing the cerebrum and cerebellum surrounding the brainstem (midbrain, pons, and medulla oblongata). Reprinted with permission from England, M.A. and Wakely, J. 1991. <u>Color Atlas of the Brain and Spinal Cord</u>.

1. Atlas
2. Axis
3. Caudate nucleus
4. Cerebellum
5. Dura mater
6. Ear
7. Falx cerebri
8. First cervical nerve root
9. Glossopharyngeal and vagus nerve roots
10. Hippocampus (a cerebral gyrus)
11. Internal capsule
12. Internal jugular vein
13. Lateral geniculate body
14. Lateral ventricle
15. Medial geniculate body
16. MIddle cerebellar peduncle
17. Posterior neck muscles
18. Parietal lobe
19. Petrous part of temporal bone
20. Pons
21. Posterior cranial fossa
22. Sigmoid sinus
23. Spinal cord
24. Accessory nerve root
25. Neck muscle
26. Superior sagittal sinus
27. Midbrain
28. Pons
29. Temporal lobe
30. Tentorium cerebelli
31. Thalamus
32. Third cervical vertebrae
33. Third ventricle
34. Vertebral artery
35. Vestibulocochlear nerve