Dissection of the Speech Production Mechanism

by

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UCLA Working Papers in Phonetics 102

2002

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Preface

One can have all the knowledge available from anatomical atlases and from textbooks on speech production, but none of it substitutes for the hands-on experience acquired in an anatomy laboratory. There is nothing comparable with actually seeing where the muscles of the tongue attach, feeling the comparative thickness of different muscles, moving the arytenoid cartilages to stretch the vocal folds, and holding a brain in one's hand.

The aim of this manual is to suggest ways of dissecting the human vocal apparatus that are appropriate for students of speech. It is designed as a short course that could be part of another, more classroom oriented, course. We hope we can encourage people working in speech pathology, phonetics, and communication sciences to find a co-operative medical department and try dissecting a human cadaver for themselves. Anatomy departments are often able to help, but we have found that a better solution is to contact people in Head and Neck Surgery, who are much more knowledgeable about the anatomy of the areas of interest to students of speech. Our best guides have been senior residents and surgeons. They have helped us go through the material in this manual in nine weekly meetings, although that has sometimes been rather rushed, and a full semester of practical work of this kind would be preferable.

This manual makes no attempt to give a detailed account of the anatomy and physiology of the speech production mechanism, presuming that is part of some other, more classroom oriented, course. Each section begins with a brief review of the actions of the different muscles that will be seen in the dissection, and the functions of different parts of the speech apparatus. But these reviews are intended simply as reminders of the information that can be found in more comprehensive books. This is a book to take into the laboratory and have in gloved hands while actually dissecting. Most of the illustrations are drawings of actual cadavers in the positions in which they are being dissected, not the upright human beings seen in many anatomical diagrams.

We assume that most readers will be students of speech, and not of medicine. As a result we have used both standard medical terminology and more familiar English forms. Thus we have used medical expressions such as "superolaterally to inferomedially", but we have also tried to help readers by noting that this means "from the upper outside to the lower inside". We are aware that the maxilla is not exactly the same as the upper jaw, but it certainly helps students to be reminded that the two are roughly equivalent. We hope that those schooled in the Latinate medical terms will forgive our attempts to make this manual as readable as possible. As far as we know, there is no dissection guide primarily directed towards students of speech.

Much of the contents in standard dissecting manuals such as Grant's dissector (Sauerland, 1984) cover anatomical areas irrelevant to the mechanism of speech production, e.g. the arms, the legs, and most of the lower abdomen. Accordingly, we have tried to produce a method of dissection concentrating mainly on the thorax, the neck and the head. Even within this limited region we have severely limited our goals. Speech scientists do not need to know how the heart should be examined, nor the appropriate way of dissecting the eye. Throughout we have emphasized only those anatomical structures that are relevant to speech. We have also placed more emphasis on the muscles rather than the nerves. For surgeons who are going to be operating on the larynx it is extremely important to know where the recurrent laryngeal nerve is likely to be, as it will be disastrous if they cut it. But for students interested in speech it is more important to know where the muscles are, what they are attached to, and what will happen when they contract.

It is difficult to say who are the authors of this book. This edition was edited and re-written by Melissa Epstein and Narineh Hacopian. Siri Tuttle researched and created new versions of all the illustrations. The manual is the cooperative effort of many generations of members of the UCLA Phonetics Lab and their colleagues in the Departments of Head and Neck Surgery and Anatomy. The first version published was UCLA Working Papers in Phonetics 77 in 1990, but that itself was the product of preceding classes. Since then the UCLA Phonetics Lab group has participated in many other dissection classes, each of them contributing to the final product. As far as we can discover, the principal participants include: Beatriz Amos, Victoria Anderson, Sean Boisen, Dani Byrd, Vanna Condax, John Choi, Sarah Dart, Ken deJong, Sandy Disner, Peter Duong, Edward Flemming, Karen Emmorey, Melissa Epstein, David Feldman, Victoria Fromkin, Juan Carlos Gallego, Bruce Gerratt, Robert Hagiwara, Narineh Hacopian, Kenneth Hill, Caroline Henton, Ren Hongmo, Kevin Hori, Marie Huffman, Sue Inouye, Michel Jackson, Patricia Keating, Jody Kreiman, Sun-Ah Jun, Jenny Ladefoged, Peter Ladefoged, Mona Lindau, Ian Maddieson, Rich Robison, Mike Suzuki, Bonny Sands, Siri Tuttle, Andrew Verneuil, Anne Wingate, Richard Wright and Ming Ye.

Introduction to dissection

We assume that the specimen available for study is a human head and torso that has been properly embalmed. Students should be aware that the actual cadaver they dissect may have individual characteristics such that the dissection procedure specified here has to be modified. Often muscles that are described in text books cannot be found in a given individual. Sometimes they are much more prominent on one side than another. The cadaver may not have teeth. People end up in an anatomy lab because they died of some cause, which may have involved a collapsed lung, or a carcinoma of some sort. They are nearly always old, and their muscles may not be as prominent as they once were.

Aside from the sights and the smells, there are the emotional issues attached to working closely with a cadaver. Starting with the torso and leaving the head covered is the easiest approach to a situation that some may find difficult. Instructors are advised that they should see that the lab is set up in this way. However, they should also encourage students to take an active part in the dissection. After a while the task will become more fascinating than unpleasant. But it should always be remembered that there are times when some students may need to take a step back and take a few minutes to adjust to the dissection that is going on. At these times it is suggested that students simply pause and take notes or make drawings of the dissection process. Some people find that a 20-30 minute walk after a dissection class minimizes the effects that the sights, smells and embalming fluids may be having on their brain.

Latex-free gloves should always be worn during a dissection. The tools needed for dissection are a scalpel, a blunt-ended probe, a pair of scissors, and a pair of blunt-pointed forceps. In addition, larger tools such as a bone saw, a pair of shears, a mallet and a chisel are occasionally necessary. The availability of an electric autopsy saw is invaluable in speeding up certain procedures such as the opening up of the skull. If the anatomy lab does not have proper lighting that can be pointed in different directions, then a flashlight is useful. Students should dress appropriately, in clothes that they do not mind getting messy. Everybody dissecting should wear a laboratory coat and perhaps a scarf over the hair so that they can emerge less smelly. Those with long hair should tie it back. Copies of this manual and other books taken into the lab should be protected by slip on plastic covers.

It is useful to have a plastic or real skull available. Anatomical reference books are also needed. There are several books that describe the anatomy and the physiology of the vocal apparatus, notably Hardcastle (1976), Zemlin (1981), and Dickson and Maue-Dickson (1982). Students are encouraged to study relevant parts of these books before each dissection in order to gain a theoretical understanding of the speech production mechanism. Further suggestions for reading appear in the annotated bibliography in Appendix C. There is an excellent atlas specifically for speech and hearing scientists by Kahane and Folkins (1984). We hope that this manual will help students take a small step towards preparing dissections like those shown in the wonderfully detailed photographs in that book. They illustrate model dissections that students should try to emulate.

After any dissection some parts of the cadaver will have been cut away. If they are definitely of no further interest, they can be disposed of in the proper container. In most cases the laboratory staff will arrange for them to be incinerated. Whenever possible, the skin should be retained and simply folded back. The skin of the specimen is a good protection against drying. When parts of the skin are not available, care should be taken to prevent the body from becoming too dry by wrapping it in cheesecloth dampened with a suitable preserving fluid. When the cadaver has been put away for the next dissection, all the dissection tools should be cleaned and stored safely, Needless to say, everyone working on the dissection should also wash thoroughly before leaving the lab.

A glossary of anatomical terms will be found in Appendix A. We will use the standard anatomical convention of referring to the cadaver as if it were standing erect with the arms straight down by the sides. This is not the position of the cadaver during dissection or in most of the illustrations, but it allows for a common basis for all descriptions. Thus, even if the cadaver is shown as lying on its back, the sternum (breast bone) is described as being inferior to (below) the head. The terms for the different directions are illustrated in Figure 0.1

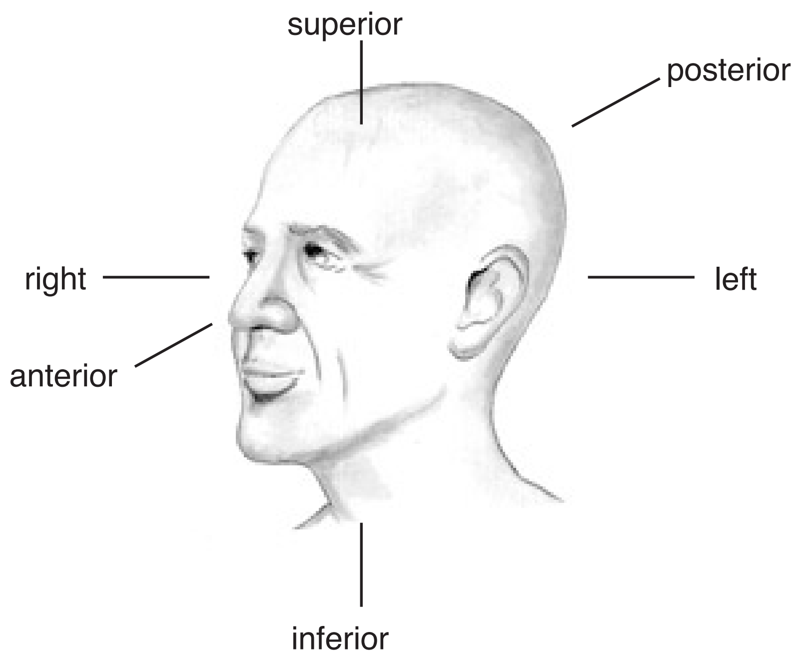


Figure 0.1 The directions used in describing the position of one anatomical structure relative to another.

Other terms related to directions are: Medial, which is defined as nearer to the center, the midline of the body; Lateral, which is defined as away from the midline (a fixed line that could be drawn along the center of the cadaver, from the head downwards); Deep, which is defined as more internal than something else; Superficial, which is defined closer to the surface of the body than something else.

There are also names for slices through a cadaver. The most familiar to students of speech is the sagittal section, shown in figure 0.2. Note that a sagittal section is any slice in parallel to the one shown. The slice that is most well known to us is the one in the mid-line, a mid-sagittal section.

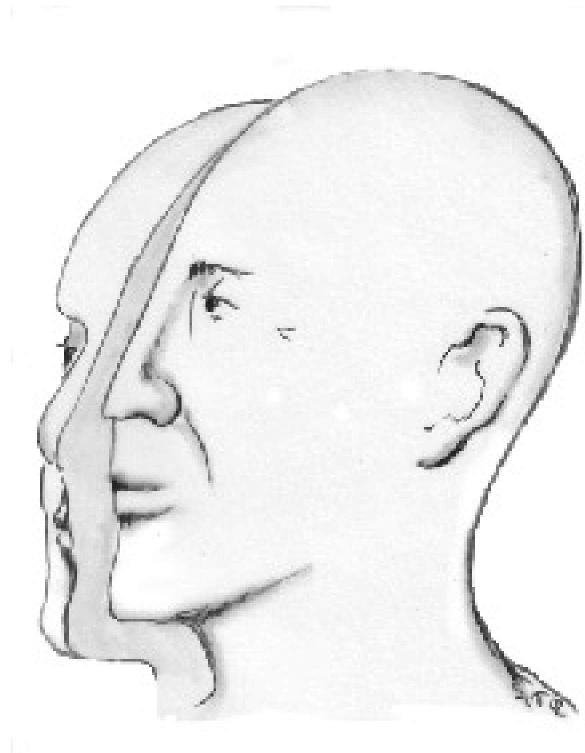


Figure 0.2. A sagittal section.

There are two other sections that are less familiar to students of speech, the coronal section and the transverse section. A coronal section is one that goes from side to side (perhaps ear to ear), vertically, as shown on the left in figure 0.3. Note that this use of 'coronal' is different from the linguistic use, in which articulations made with the crown of the tongue are called 'coronal'. A transverse section, also shown in figure 0.3, is a horizontal slice.

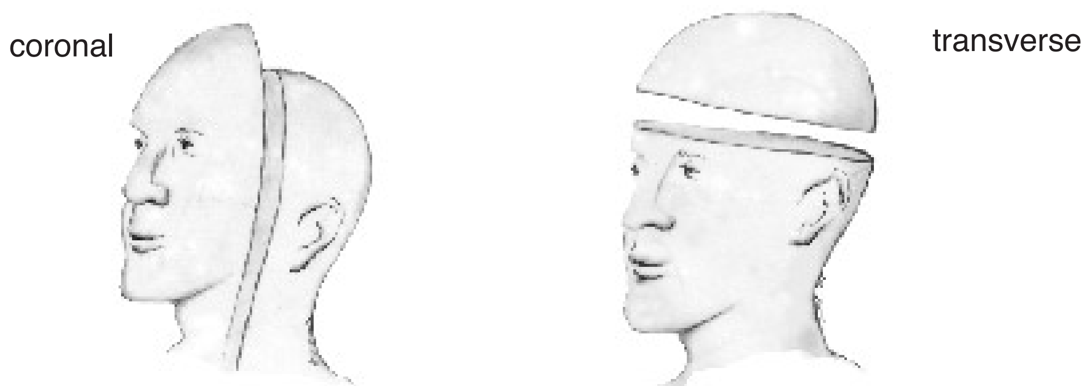


Figure 0.3. Coronal and transverse sections.

Appendix B contains a list of all the most important muscles of the speech production mechanism, arranged in accordance with their function. Students should review appropriate sections of this list periodically, so as to ensure that they have seen all the muscles named. The annotated bibliography in Appendix C contains references to some useful supplementary materials.

1. The Respiratory Mechanism

Overview and objectives of this dissection

The principal aim of this dissection is to observe the muscles that control the flow of air required for speech. Air is drawn into and pushed out of the lungs by the action of the respiratory muscles shown in figure 1.1. Speech involves first filling the lungs with air and then pushing this air out so as to supply sufficient power for the production of the various sounds

The volume of air in the lungs depends on the size of the thoracic (chest) cavity, which is bounded by the **ribs** and the **diaphragm**, a large dome shaped muscle separating the thoracic cavity from the abdominal cavity. The thoracic cavity can be enlarged by raising the rib-cage with the **external intercostal** muscles, or by contracting (and hence lowering) the diaphragm. The external intercostals are attached between the ribs and are most prominent laterally and posteriorly (at the side and the back). Anteriorly (in the front) at the **costochondral** junction (near where the ribs attach to the **sternum**, the breast bone), they are replaced by a membrane which attaches to the sternum. The direction of the muscle fibers is the same as that of the fingers insertednto the front pockets of the pants i.e. posterosuperiorly to anteroinferiorly (from abovand behind to below and in front).

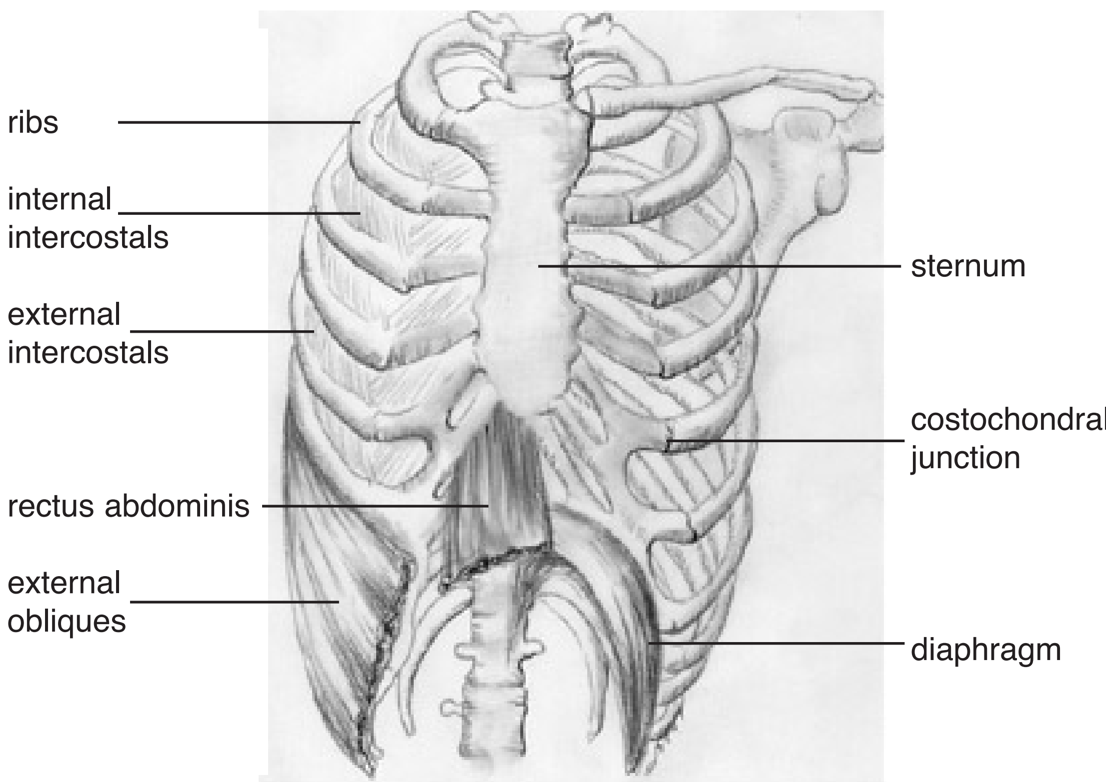


Figure 1.1. The respiratory mechanism. (In this, as in many of the figures in this manual, sometimes only one part of a paired muscle or structure is shown.)

Without the action of inspiratory forces such as the external intercostals and the diaphragm, the lungs collapse back to their resting state. Normal expiration is entirely passive. The more the lungs are inflated, the greater their tendency to return to the resting position. This restoring force is known as the elastic recoil of the lung. It produces the relaxation pressure, the air pressure in the lungs that occurs when there are no inspiratory forces and the flow of air out of the lungs is impeded.

In speech, the task is to produce a relatively constant positive air pressure in the lungs, despite the varying relaxation pressure. During normal conversation, this is achieved by the expiratory action of the **internal intercostal** muscles. Usually these are the *only* respiratory muscles active in quiet speech. The internal intercostal muscles are situated deep to (inside) the external intercostal muscles and their muscle fibers run posteroinferiorly to anterosuperiorly (from behind and below to above and in front). This is the direction of your fingers if you cross your arms on your chest and let your fingers point up towards your shoulders. Contracting the internal intercostals pulls the ribs together, thus forcing air out.

The size of the thoracic cavity can also be reduced by pushing up on the diaphragm. The **rectus abdominis**,(the "abs" in body builder's terms) and the **external obliques** (the muscles on your sides on top of your ribs) are mainly used for controlling the posture of the body, but when they contract they decrease the size of the abdominal cavity, and, as a result push the diaphragm upwards, and assist in pushing air out of the lungs. Major activity of these muscles usually occurs only at the end of an utterance when action of the internal intercostals alone is not sufficient to produce the required pressure.

This dissection also allows you to observe that the lungs are inside the **pleura**, which will be illustrated later. The pleura form the lining of the **thoracic** cavity. The part of the pleura attached to the thoracic wall is the **parietal pleura**, and the part surrounding the lungs (and other organs) is the **visceral pleura**. The visceral pleura surrounds the cavities containing the lungs. As the rib cage is raised, or the diaphragm is lowered, these cavities are enlarged. The enlargement of the thoracic cavity during inspiration results in a decrease in the pressure in the pleural cavity To prevent a vacuum (or, at least, too great a lowering of the intrapleural pressure), the visceral pleura expands, and this in turn forces the lungs to expand. Schematically the lungs are like a pair of balloons being filled by suction from the surrounding cavity. When a balloon is inside a jar, removing the air from the jar will make the balloon expand.

Bearing all this in mind, at least the following anatomical structures should be observed during the first dissection: the **external** and **internal intercostal** muscles, the **ribs**, the **diaphragm**, the **external oblique** muscles, the **rectus abdominis** muscle, the **lungs** within the **pleura**, and the **trachea**. As many measurements of subglottal pressure during speech are inferred from pressures recorded in the **esophagus**, its anatomical relationship with the **trachea** should also be noted. You will also have to remove other muscles that will be described in the course of the dissection, in order to see these structures.

Students should refer to Kahane and Folkins (1984), figures 2-1 to 2-23.

Before you begin

Before beginning the dissection, you should take a few minutes to familiarize yourselves with the cadaver. In particular, you should review the anatomical planes as presented in the Introduction. Also, observe the cadaver from the outside, noting tubes and incisions from surgery and/or the embalming process. Before taking the scalpel in hand, open the anatomy atlas to the appropriate pages and put on gloves. Remember that every cadaver has two halves, so two people can be performing the same dissection simultaneously, as long as the structures of interest are symmetrical.

Exposing the rib cage

1. Place the cadaver on its back. (see Figure 1.2) In the midline (a fixed line that could be drawn along the center of the cadaver, from the head downwards) feel the jugular notch (also called the sternal notch) in the breast bone below the neck. Make a skin incision from the jugular notch along the clavicle (the collar bone) out towards each arm.

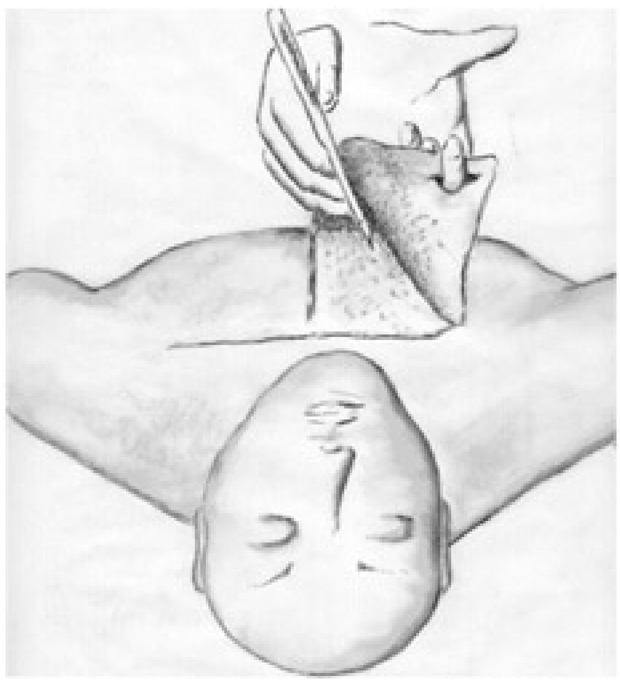


Figure 1.2 Skin incisions for exposing the rib-cage.

2. Make a midline incision from the jugular notch down to the cut edge of the torso. If a complete cadaver is used, continue the incision to 5 cm below the umbilicus (the belly button); a further incision will have to be made from this point laterally (out to the side) to the edge of the abdomen.

   Peel away the skin beginning at the jugular notch. Do so by reflecting (pulling back) a corner of the skin and making a small incision about a centimeter away from and parallel to the corner in order and insert a finger into this incision. By pulling on this flap with the flexed inserted finger, the skin can be more easily separated from the underlying fascia (the lining between muscles or between muscles and the skin) with a sharp scalpel. The scalpel blade should be aimed upward towards the skin to avoid damage to the underlying musculature (Figure 1.2). Reflect laterally the complete rectangle of skin from the clavicle down to the inferior (lower) edge of the torso (or the inferior incision line). Try to keep the skin all in one piece so that it can be used to cover the body at the end of the day's dissection. Scrape or pick away underlying fatty tissue with a scalpel and forceps, until all muscles are revealed.

3 Locate the pectoralis major muscleThe pectoralis major's medial (midline) attachments are along the clavicle, thsternum and the ribs (Figure 1.3), its lateral attachments are on the upper arm

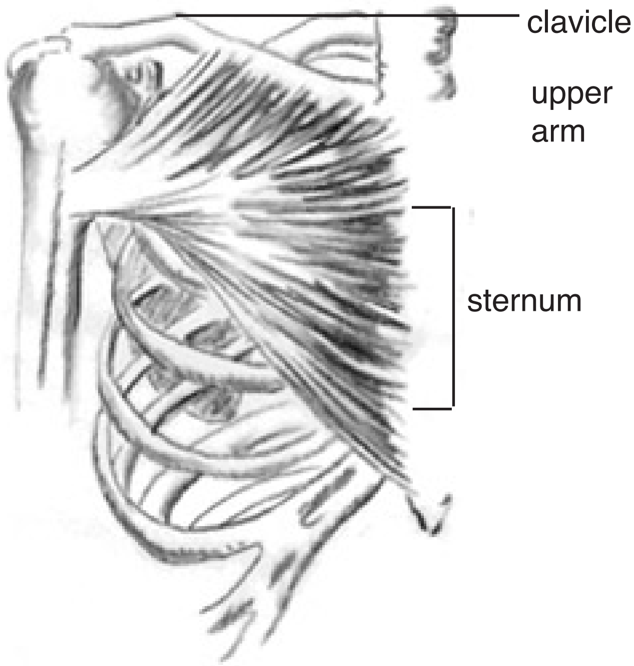


Figure 1.3 Pectoralis major.

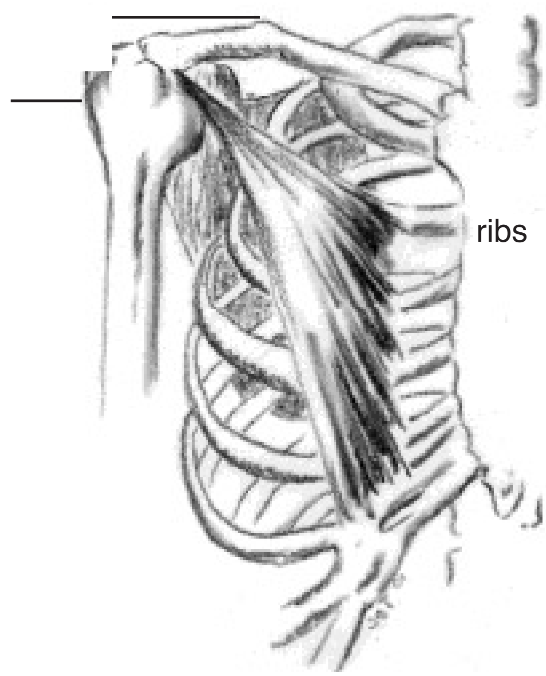
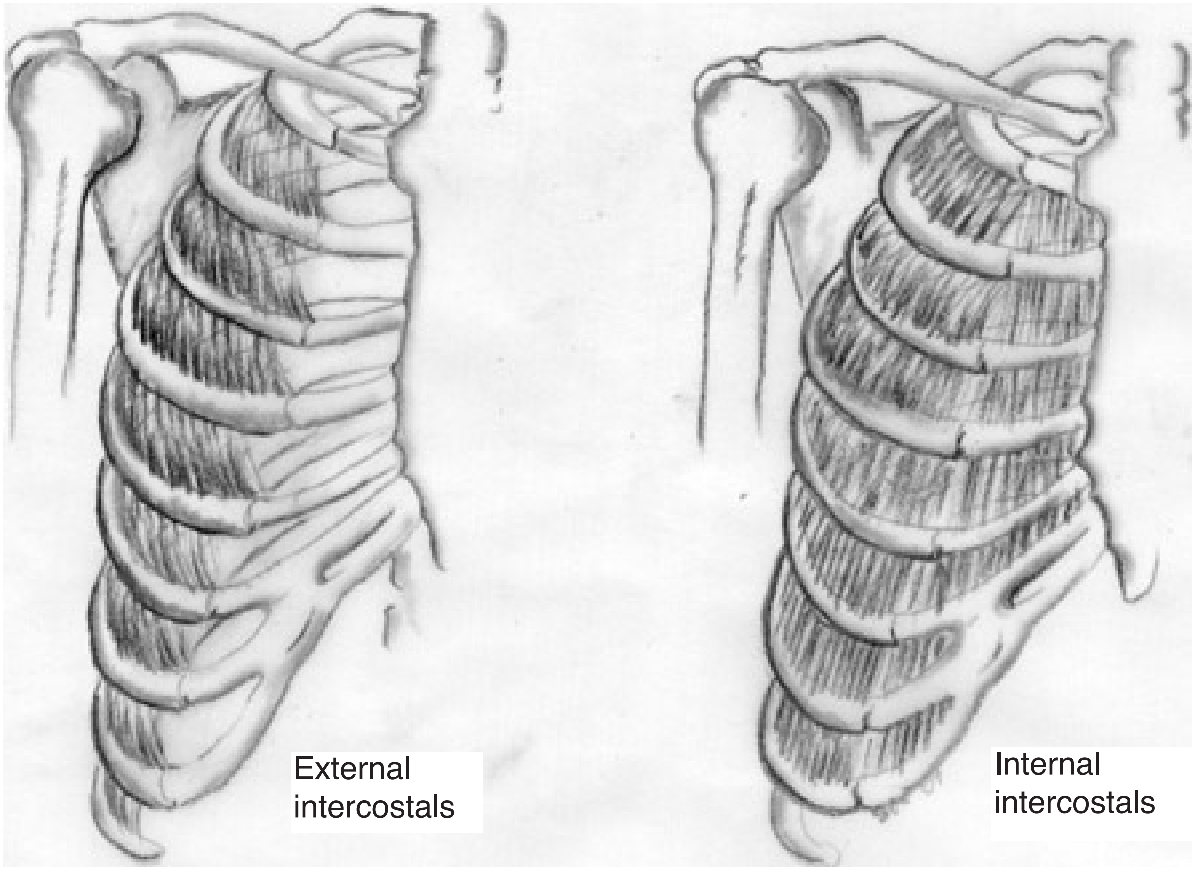


Figure 1.4 Pectoralis minor

4. Remove the pectoralis major by inserting a probe underneath it, starting along the upper arm, and lifting it away from all underlying structures. Cut the muscle along its medial and inferior attachments and reflect it towards the arm. This will expose the pectoralis minor.
5. The pectoralis minor is attached anteriorly (in front) to ribs 3, 4 and 5. (See figure 1.4.) Detach this muscle from its insertions into the ribs and reflect it towards the shoulder.
6. Locate the external intercostal muscles between each rib (Figure 1.5). From the front, they can be seen best in the area to the side of and under the pectoralis minor.

Note that the external intercostal muscle fibers run superolaterally to inferomedially (from top at the side to the bottom middle) and the muscle does not extend all the way to the sternum. The direction of the fibers is the same as that of your forearms when putting your hands into your pockets. The external intercostal muscle fibers change to membrane as you move from the bony ribs to the cartilaginous ribs to the sternum. This membrane is



easiest to see on the superior (upper) ribs where you can even observe the internal intercostal muscle fibers through the external intercostal membrane.

Figure 1.5. The external and internal intercostal muscles. External intercostals, which are involved in lifting the rib cage and thus causing inspiration, are shown on the left of the figure. Internal intercostals (on the right) cause controlled expiration (as in egressive pulmonic airflow) by lowering and contracting the rib cage.

7. Peel the external intercostal membrane upwards to reveal the internal intercostal muscles as shown in Figure 1.6. Insert a probe in the plane between the external intercostals and the internal intercostals, then cut the external intercostals along one rib and reflect them upward.

   The internal intercostal muscles are most prominent near the midline at the inferior part of the thoracic cage (around ribs 9 and 10). Note that the fibers of the internal intercostal muscle run superomedially to inferolaterally (from the top middle to the bottom side). This is similar to the direction of your forearms when crossing your arms on your chest.

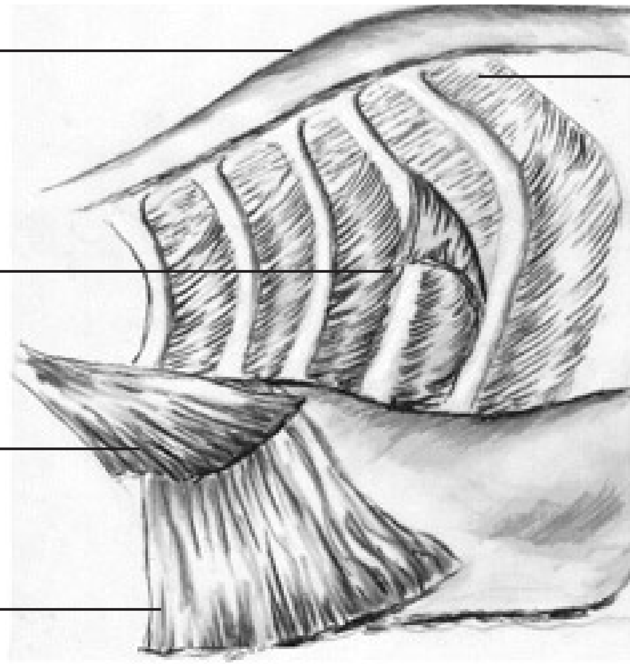


Figure 1.6. Reflecting the external intercostals. (Viewed from over the right shoulder. The headwould be to the left).

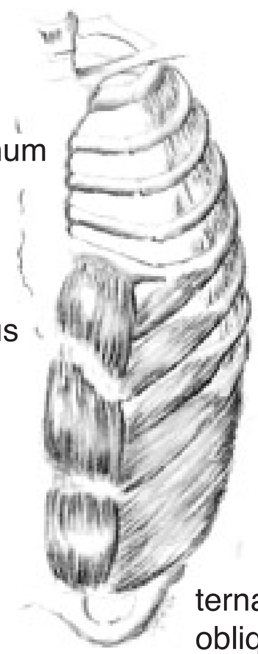


Figure 1.7. Left rectus abdominis and left external oblique

8. Locate the rectus abdominis muscles near the midline (Figure 1.7). They are attached to the costal margin (the lower edge of the rib cage) and can extend superiorly as high as the posterior aspect of the fifth costal cartilage (the back of the cartilage of the fifth rib).

9. Locate the external and internal oblique muscles.

   The external obliques lie lateral to the rectus abdominis muscles, (Figure 1.7) and sweep downward and medially from the bony part of the lower ribs to the pelvic bone. Their fibers run in the same direction as the fibers of the external intercostal muscles.

   Reflect the external oblique muscle to expose the internal oblique muscle.

   The fibers of the internal oblique muscle sweep upward and medially from the pelvic bone to the cartilaginous part of the lower ribs, in the same direction as the fibers of the internal intercostal muscles. If only a torso is available for dissection, these abdominal muscles will be sectioned close to their attachments to the costal margin.

Depending on the time available, the following may be left to a second dissection session, With this in mind, the numbering of the instructions has been started again at 1.

Opening the thoracic cavity.

1. Cut along the side of the sternum and reflect the ribs laterally, using a saw or a strong pair of scissors as shown in figure 1.8. Be aware that reflecting the ribs may cause them to break. This procedure may be done on either one or both sides of the rib cage.

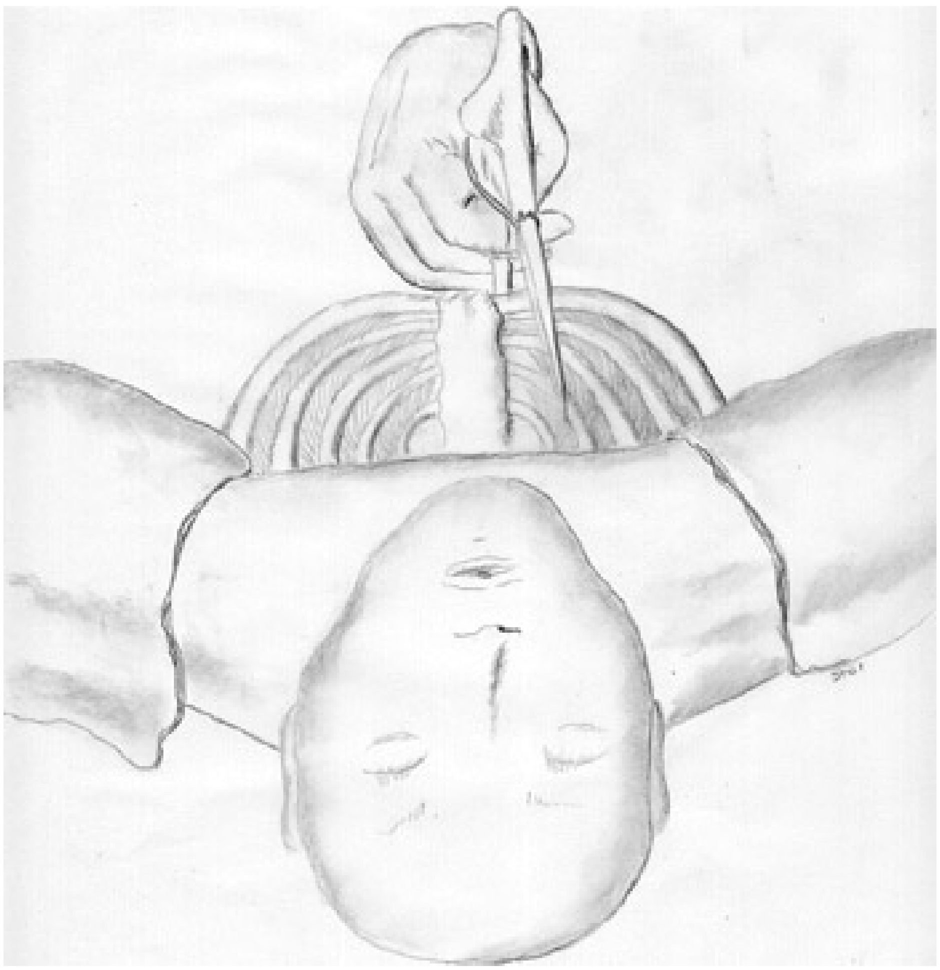


Figure 1.8. Opening the thoracic cavity.

2. Locate the pleura, the membrane surrounding the lungs, inside the rib cage. There are two parts to the pleura, the outer or parietal part is attached to the interior of the rib cage, and the inner or visceral part, is attached to the lungs. The two layers are actually part of a single sheet, folded in on itself. The external part of the pleura may be seen on the interior of the reflected part of the rib cage.

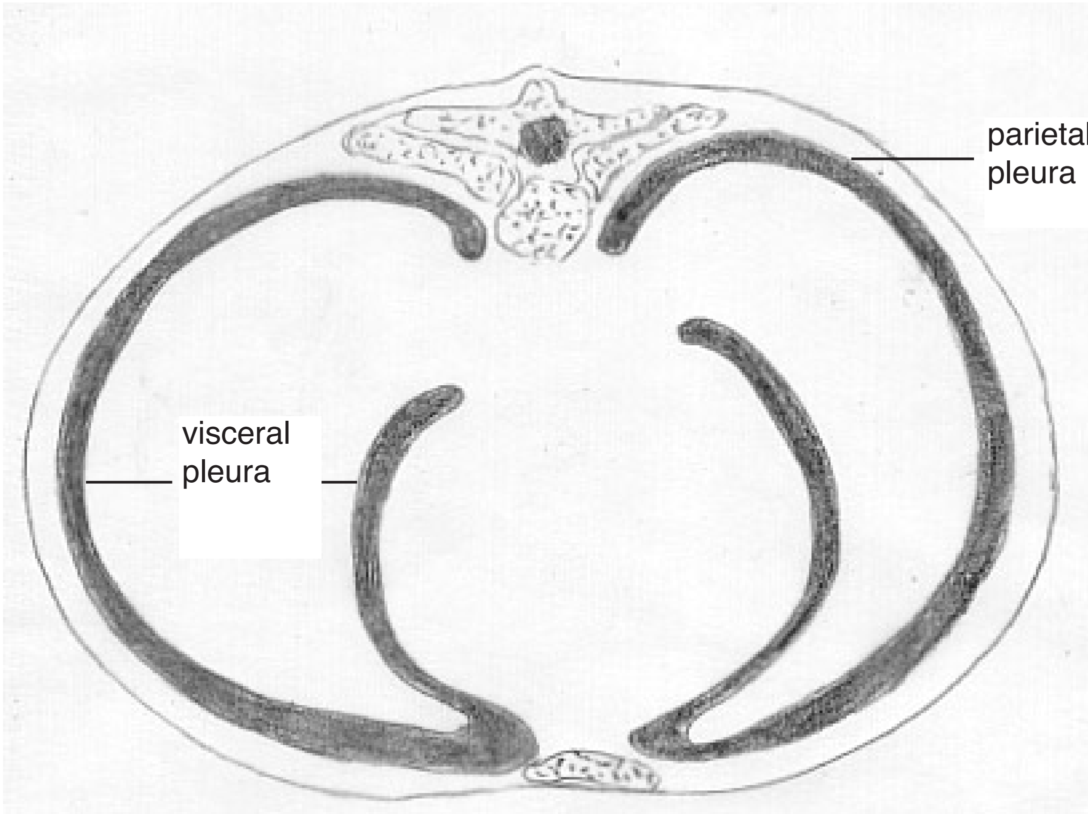


Figure 1.9. A schematized coronal section of the pleural layers, showing them as a single continuous membrane.

3. Locate the left and right lungs, remembering that *left* and *right* refer to the cadaver's perspective, not your own (figure 1.10)

   The right lung has three lobes and the left lung has two lobes. Additionally, the left lung is smaller than the right lung because the heart, within the pericardial sac, lies slightly to the left of the midline. The lungs may appear to be quite small because they are usually partially deflated. Some cadavers' lungs may have black streaks or spots from smoking or exposure to air pollution. Note the spongy consistency of the lungs.

   The slightly larger right lung is divided into a superior, a middle and an inferior lobe by the oblique and horizontal fissures. The left lung is divided only by the oblique fissure into a superior and an inferior lobe. Observe that the visceral pleura extends into these interlobar clefts.

   Study the root of the lungs where the bronchial tubes, pulmonary arteries and veins are grouped together. This close relationship between the air ducts and the blood vessels is maintained deep into the substance of the lungs, to facilitate gas exchange. If time permits, dissect a lung by following a bronchus down its branching structure.

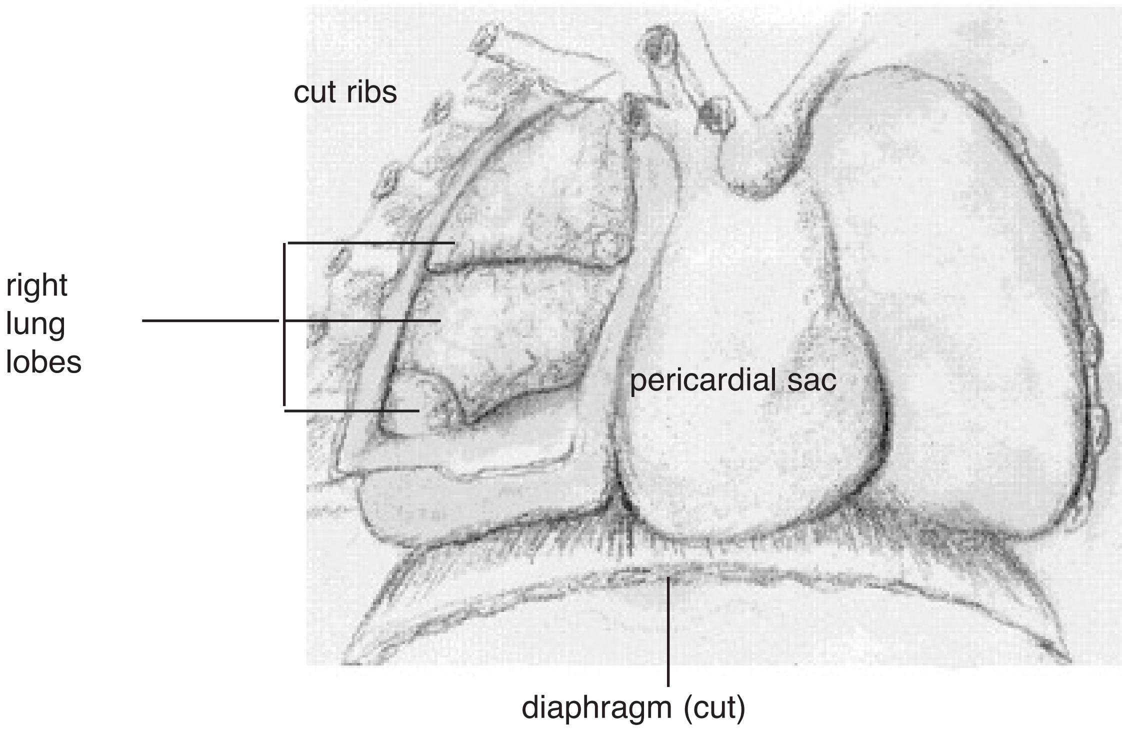


Figure 1.10. Structures of the thoracic cavity. The heart is within the pericardial sac.

4. Reflect back the oblique muscles and the rectus abdominis muscle to reveal the abdominal cavity.

   Locate the diaphragm and its attachments inside the rib cage and the thoracic cavity (Figure 1.11).

   The diaphragm muscle is like a large inverted bowl dividing the abdominal and thoracic cavities. The muscle fibers of the diaphragm radiate out from the central tendon and form sternal, costal and vertebral attachments.

   Contraction of the diaphragm pulls the top of the "inverted bowl" in and down expanding the thoracic cavity.

   Observe the domes of the diaphragm from underneath by removing the contents of the abdominal cavity, particularly the liver. Note that the diaphragm is pierced by three structures: the aorta at the level of thoracic vertebra 12 (T12), the esophagus at T10 and the inferior vena cava at T8. Shine a light into the area beneath the diaphragm to see these structures.

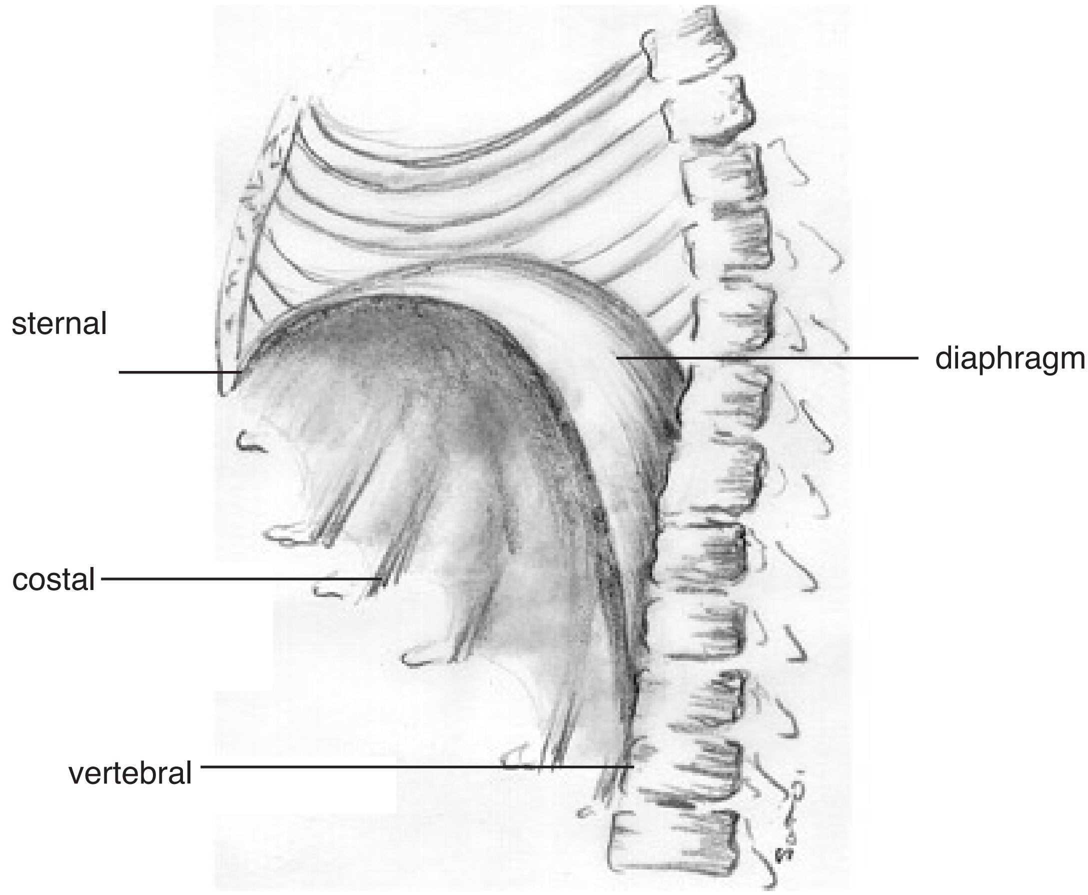


Figure 1.11. The diaphragm and its attachments.

5. Return to the upper torso to observe the relationship between the trachea (windpipe) and esophagus. Identify the individual tracheal rings, noting that they are actually C-shaped cartilages bound posteriorly by a sheet of smooth muscle called the trachealis (figure 1.12). This shape allows for the expansion of the esophagus when food is being swallowed. The expansion is necessary because the esophagus is bounded posteriorly by the bony vertebrae of the spinal column. Because only a thin sheet of muscle separates the trachea from the esophagus, the subglottal (tracheal) air pressure can be approximated by measurement of the esophageal air pressure.

   The trachea divides above the lungs into two bronchi which are composed of cartilaginous rings bound together by fibroelastic and smooth muscle tissue. Since all cartilage ossifies (becomes bony) with age, depending on the age of your cadaver, the cartilages of the bronchi and trachea may be more or less bony.

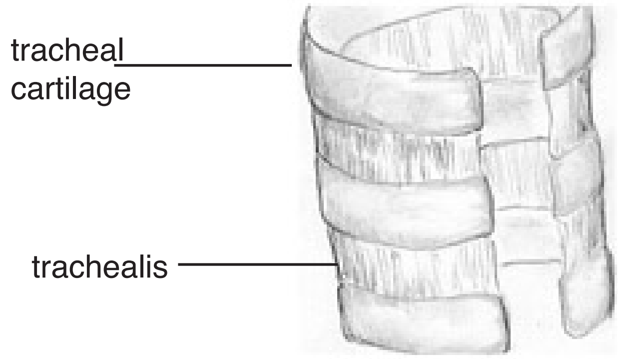


Figure 1.12. The tracheal rings, showing the C-shaped ‘open ring’ structure.

2. The Lips

Overview and objectives of this dissection

The principal aim of this dissection is to observe the muscles that are used for moving the lips, shown in figure 2.1.

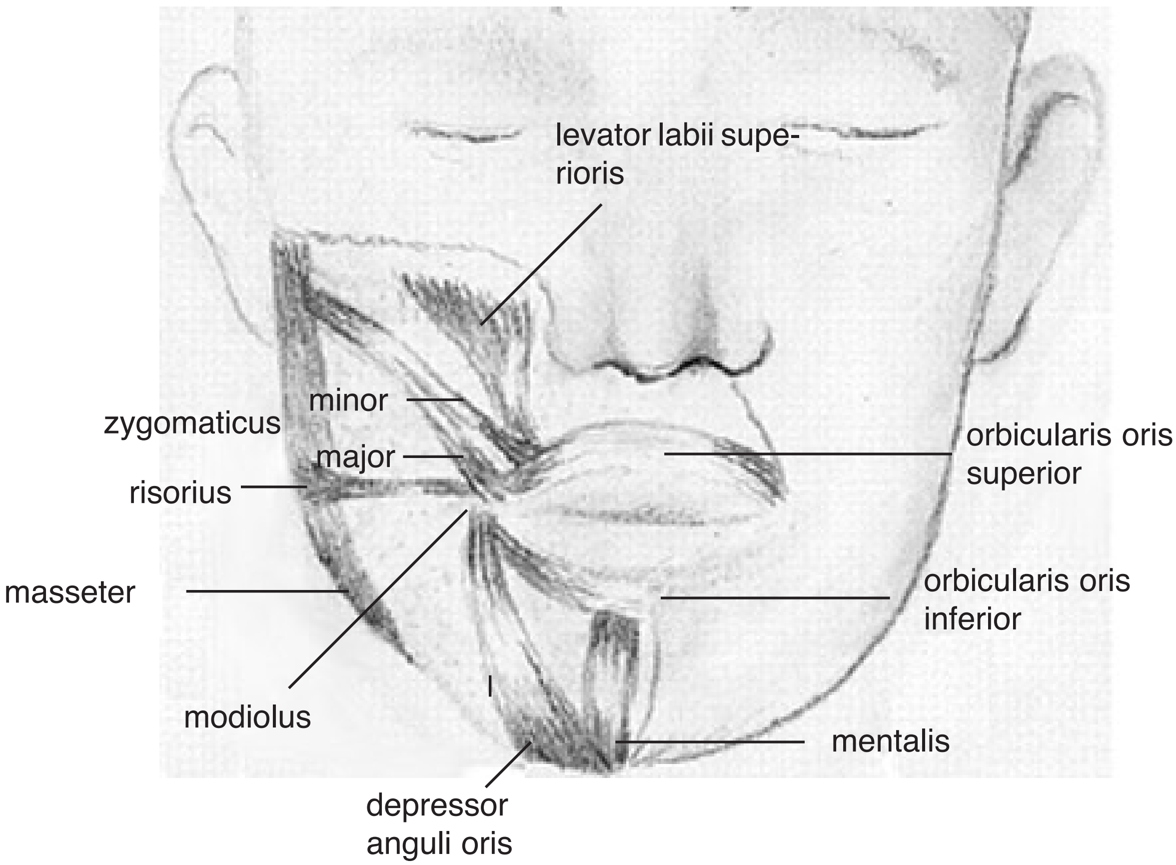


Figure 2.1. Muscles for moving the lips.

From a phonetic point of view there are three major movements of the lips:

(a) *Rounding-spreading* (the corners of the lips are drawn together or pulled apart). Rounding is achieved largely by the action of the **orbicularis oris muscle**, (the muscle that encircles the lips). This is a sphincter muscle, a circular band of muscle fibers that constrict an opening, like a purse string. It acts in opposition to the **zygomaticus major** (and minor), the buccinator, and the **risorius** muscles (the muscles that extend outward and backward from the lips) all of which are dilator muscles, enlarging the opening.

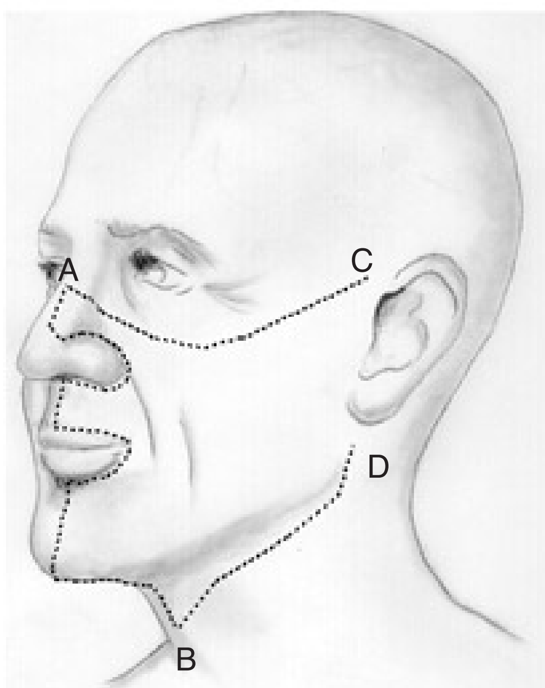
(b) *Protrusion* (the lips are pushed forward, making the vocal tract longer). Protrusion involves the lower lip more than the upper. For the lower lip, the mentalis and the **depressor labii oris**, the muscles from the lips to the chin play the major roles. The turning of the upper lip outward is achieved by the **levator labii superioris** and the **zygomaticus minor** (muscles extending upward and backward from the upper lip).

(c) *(Vertical) Compression* (the lips come together, mainly by the lower lip being raised). Vertical compression occurs without lip rounding, mainly by raising the lower lip while raising the jaw (see next chapter for jaw raising). Some vertical compression can be achieved without raising the jaw by the actions of the inferior part of the orbicularis oris muscle (the muscle encircling the lips) and the mentalis muscle (the muscle from the lower lip to the chin).

The major anatomical structure to observe in this dissection is the **modiolus**, the point near the corner of the lip where a number of muscles come together. The muscles to be identified are illustrated in Kahane and Folkins (1984), chapter 11. Note in particular their figures 11-3, 11-4, 11-5 and 11-11, all of which contain photographs of excellent dissections that students should try to replicate. Their figure 11-7, showing the way in which the facial muscles blend into one another, is a salutary reminder of the difficulties of achieving dissections showing the separate muscles.

Dissecting the lip muscles

The dissection of the facial muscles is particularly difficult because the muscles are close to the skin and may not be easily distinguished from the surrounding tissue. Do not worry too much about accidentally cutting a muscle, being unsuccessful in finding a muscle or having difficulty distinguishing among the muscles. In short, the goal of this dissection is



to have a good general picture of the structure of the facial muscles, rather than identifying any one muscle.

Figure 2.2 Skin incisions required for dissection of the facial muscles.

1. Make three incisions on the cadaver's face, as shown in Figure 2.2

   Make incision AB in the midline from the nose down to the previously cut skin at the level of the clavicle. The incision should go around the nostrils and lips.

   Make incision AC from the midline to a point just in front of the top of the ear, going below the eye. Alternatively, incision AC may be made up to the eye. Then you can observe that the muscle surrounding the eye socket is the same kind of "purse string" muscle as the muscle surrounding the lips.

   Make incision BD on the side of the face below the angle of the mandible.

2. Reflect the skin, beginning at either the clavicle, the nose, or the ear. The best location for beginning this dissection will vary with the cadaver and the skill of the dissector. You may have to change your approach to the dissection. Suggestions are:

   It is easier to begin in the area of the cheek where there will probably be considerable subcutaneous fat that makes the removal of the skin easy.

   It is more difficult to work nearer the lips because the muscles are directly attached to the skin. You may decide not to remove the skin from around the lips until you are ready to observe the muscles in step 6.

   In all cases point the blade of the scalpel towards the skin, to avoid damaging the muscles immediately below. Also, try to reflect the skin back in one piece, as much as possible, so that the skin may be used to cover the face after the dissection.

3. Remove the parotid gland (a salivary gland) and the fatty pads above the zygomaticus major muscle in the region of the cheek. Note the seventh (facial) nerve, which goes through the parotid gland.

4. Locate the zygomaticus major muscle which connects the zygomatic arch (the cheekbone) to the upper lip. Follow the zygomaticus major from its origin on the zygomatic arch down to its insertion into the modiolus near the corner of the lip, as shown in Figure 2.2. The modiolus is the point at the corners of the lips where several muscles converge.

5. Find the other muscles that join at the modiolus. Six muscles come together at the modiolus: (1) the zygomaticus major, (2) the orbicularis oris (both the superior and inferior muscles), (3) the levator anguli oris, (4) the risorius, (5) the buccinator and (6) the depressor anguli oris. The movements of the modiolus are central to the actions of lip rounding and lip spreading.

   The orbicularis oris muscle is the "purse string" muscle surrounding the lips.

   The levator anguli oris muscles and the risorius muscles are close to the zygomaticus major. The risorius may be very thin or even absent.

   The fibers of the buccinator muscles (one of the muscles of the jaw) also insert into the modiolus. The buccinator is deep to the zygomaticus major, and will be apparent only after all the fatty pads of the cheeks have been removed.

The depressor anguli oris muscles extend from the chin to the lower lip.

6. Finish removing the skin on the upper lip, and try to identify the following muscles: the superior portion of the orbicularis oris, the levator labii superioris, the zygomaticus minor and the levator labii superioris alaeque nasi. These last three muscles can be used to raise and (to a small extent) protrude the upper lip.

7. Finish removing the skin around the lower lip and note how the fibers of the orbicularis oris surround the lips, enabling it to have a kind of purse string action. Students may also wish to observe the orbicularis muscle around the eye. These two muscles are also called sphincter muscles.

8. Locate the two muscles involved in the protrusion of the lips, the depressor labii inferioris and the mentalis. Find the origin of the depressor labii inferioris muscle on the mandible, and its insertion into the orbicularis oris. The mentalis connects the lower lip to the chin. To find the mentalis cut in the midline below the lower lip to the mandible itself, thus splitting the fatty pad forming the chin. The mentalis will also be split and may be observed along the cross-section under the fatty pad.

3. The Jaw and Related Structures

Overview and objectives of this dissection

The goal of this dissection is to observe the muscles of jaw raising. You will also have the opportunity to observe several nerves that run along the side of the face and the jaw. The position of the jaw is important in speech in that it considerably affects that of the tongue. It also plays a prominent role in consonant production, particularly that of labial consonants such as [p, b, m, f, v]. In addition, proper positioning of the upper and lower front teeth (the incisors) is required for the pronunciation of sibilants such as [s]. In this dissection we will study the muscles responsible for raising the jaw. Jaw lowering will be considered in Dissection 4.

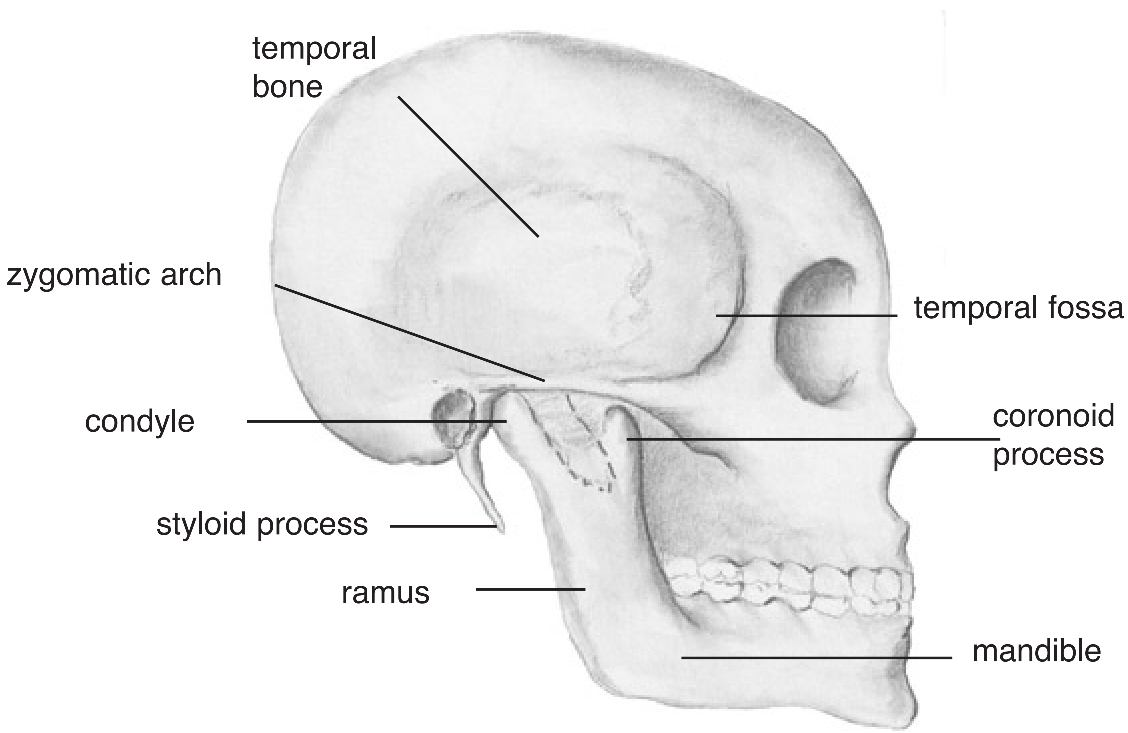


Figure 3.1 Landmarks of the skull, lateral view.

In approaching structures of the deep face, it will be helpful to note a number of reference points on the exterior portions of the skull. You should also feel these on your own face, as well as finding them on a real (or plastic) skull. The locations of many of the features named below maybe hard to find simply by reference to two-dimensional illustrations such as figures 3.1 and 3.2. The first useful landmark on the **mandible** (the jaw) is the **condyle**, which forms part of the temporo-mandibular joint, the hinge of the jaw. It is in front of your ear and below the cheekbone on the upper part of the jaw. Observe how the mandible moves. Next find the **coronoid** process, (in front of the condyle going towards your nose on the upper part of the jaw), the **ramus**, the back part of the jaw bone and the **angle**, basically the angular part of the jaw bone, all of which are indicated in Figure 3.1. Note the extent of the **temporal** bone, the major part of the skull above the eyes. Find the **styloid** process, a small spike of bone (which may have been broken off) near where the ear would be, but deeper. You should try to locate this process on both sides. Also locate the **zygomatic arch** (the cheek bone), the **lateral pterygoid**

plate, and the **maxill**a (the foundation for the upper teeth).

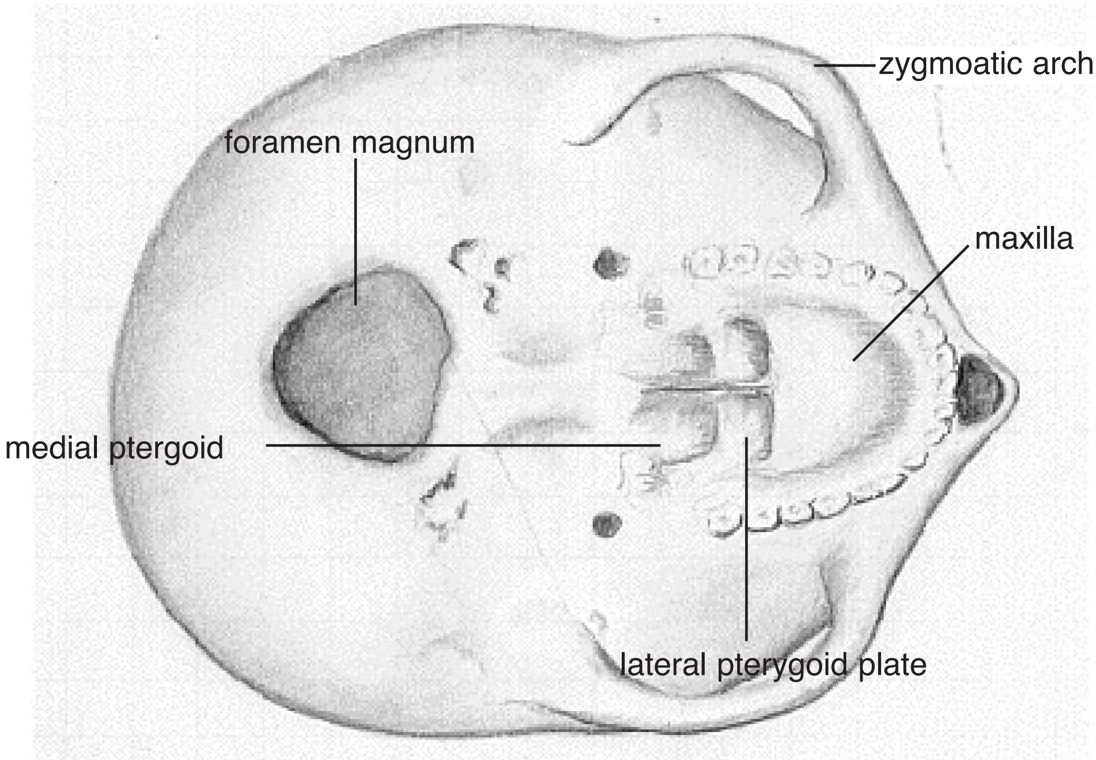


Figure 3.2. Landmarks of the skull, viewed from below

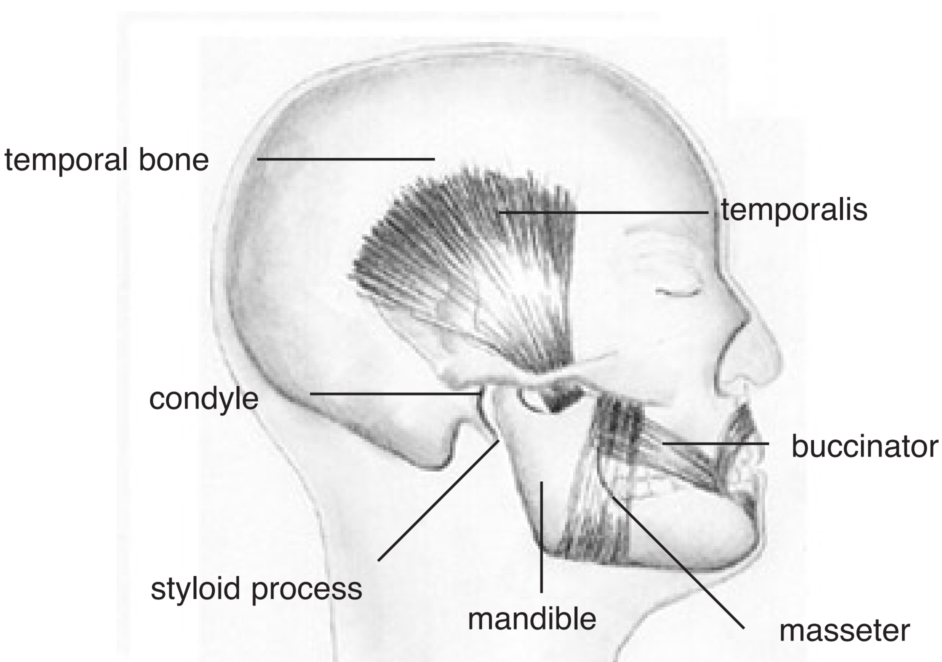


Figure 3.3. External muscles of jaw raising.

The muscles to be observed in this dissection are listed below along with their attachments and functions.

The **massete**r attaches to the zygomatic arch and to the ramus of the mandible (more colloquially, from the cheek bone to the back of the jaw). It closes the jaw by elevating and drawing forward the angle of the mandible. See Figure 3.3.

The **buccinator** lies deep to the masseter and is the muscle of the cheek-pouch. See Figure 3.3.

The **temporalis** arises from the temporal bone and attaches to the coronoid process of the mandible. The anterior two thirds of the temporalis muscle help to elevate the mandible. The posterior third retracts the mandible. This is the only muscle that retracts the mandible. See Figure 3.3.

The l**ateral pterygoid** muscle (figure 3.4) arises from two heads, one from the surface of the lateral pterygoid plate and one from the lateral portion of the greater wing of the sphenoid bone. It inserts into the pterygoid pit beneath the mandibular condyle (the head of the mandible). The lateral pterygoid muscle draws the mandible forward by drawing on the condyle.

The **medial pterygoid** muscle (Figure 3.4), which arises from the medial surface of the lateral pterygoid plate (see Figure 3.1) and attaches to the medial side of the angle of the mandible. By pulling the angle of the mandible towards the lateral pterygoid, that is, superiorly, anteriorly and medially, it closes the mouth.

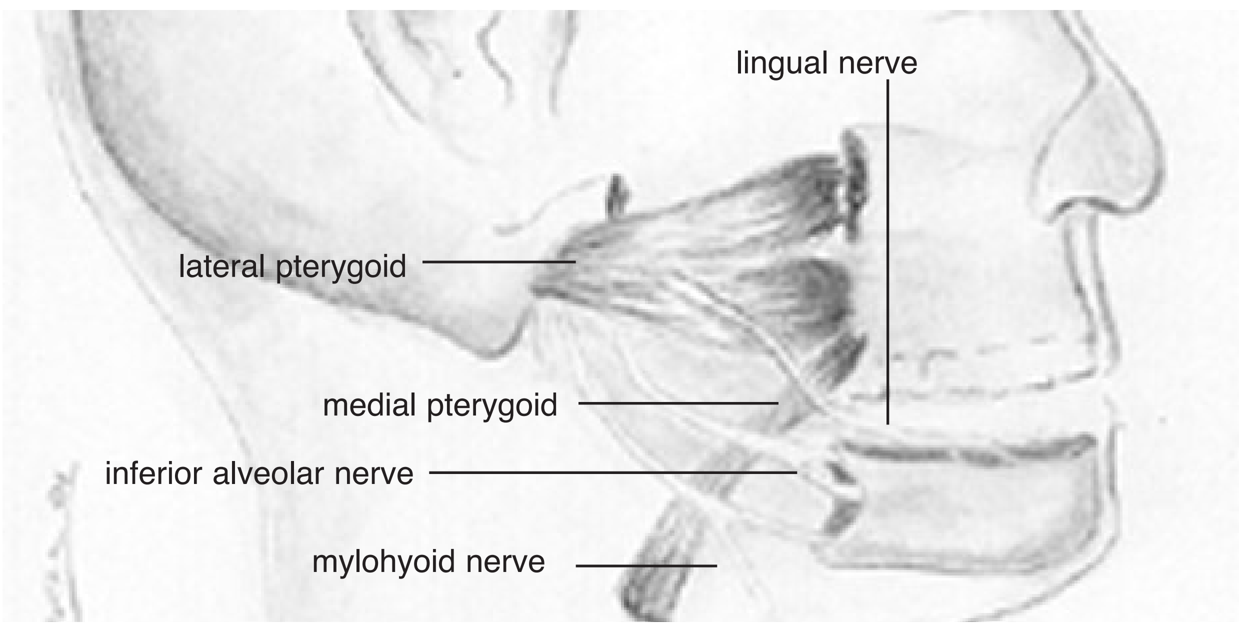


Figure 3.4. Other structures of the deep face.

The dissection also provides an opportunity to locate some of the nerves involved in speech production, shown in figure 3.4.

The **inferior alveolar nerv**e which is a branch of the posterior mandibular division of the trigeminal nerve. It innervates the teeth and also provides sensory innervation for the lower lip. This nerve runs down the side of the face and goes through the mandible.

The l**ingual nerve**, which is another branch of the posterior division of the mandibular branch of the fifth cranial nerve. It runs in front of the inferior alveolar nerve and supplies (among other things) the mucous membrane of the anterior two-thirds of the tongue.

The **mylohyoid nerve**, which is a branch of the inferior alveolar nerve. It innervates the mylohyoid muscle, and the anterior belly of the digastric muscle, which will be dissected later.

The features of the skull discussed above are shown in Kahane and Folkins (1984) in figures such as 1-5, 1-6 and 1-9. Some of the muscles in this dissection are shown in their figures 10-9 and 10-10, though the views illustrated there differ from those described below because they followed different dissections.

Dissecting the muscles that raise the jaw

Before beginning the dissection note whether or not your cadaver has or had dentures (the dentures may have been removed). This will affect the size and thickness of the mandible.

1. Make an incision along the brow towards the previously cut edge of the skin next to the eye. Pull back the cut edge of the skin, towards the ear, as far as the forehead. Underneath the skin lies the temporalis muscle covered by a very thick fascia. Clean up the area around the zygomatic arch and the temporalis muscle without removing the fascia overlying the temporalis muscle. Using chisel and mallet, crack the mandible horizontally.

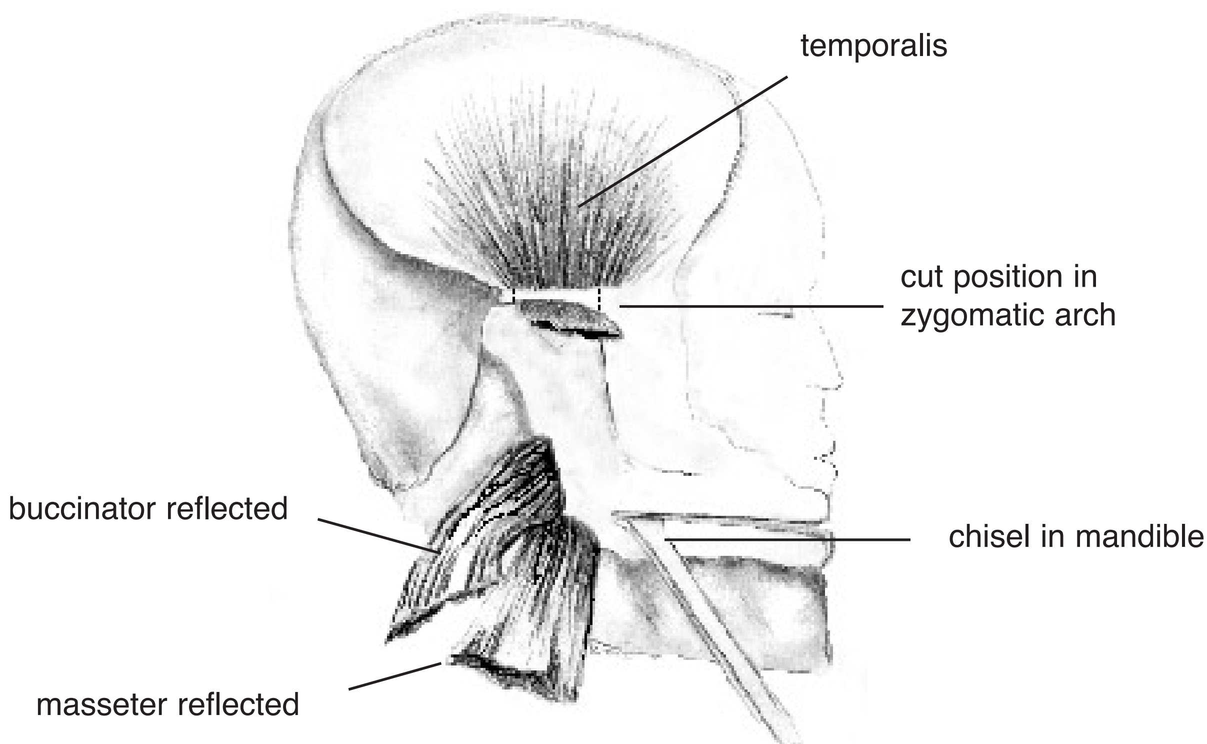


Figure 3.5. Dissection of the deep face. Cuts in zygomatic bone as indicated by dotted lines. Masseter reflected, exposing buccinator.

2. Locate the masseter muscle which connects the zygomatic arch to the mandible. Reflect the masseter down by cutting the muscle along the inferior border of the zygomatic arch.

   Examine the underside of the muscle and observe the masseteric nerve. The masseteric nerve runs superior to the mandibular notch, the recessed area between the condyle and the coronoid process of the mandible (along the top of the jaw). Look for the masseteric artery which runs between the intermediate and superficial tendons of the masseter.

3. Remove a piece of the zygomatic arch, as indicated in figure 3.5. Section the zygomatic arch, using a bone saw or heavy scissors, along the vertical axis just anterior to (in front of) the condyle of the mandible. Then, make another cut about 3 cm anterior to the first.

   Remove the cut piece of the zygomatic arch and observe the temporal fascia beneath it. Notice the attachment of this tissue in the temporal fossa, the middle portion of the skull.

4. Section and reflect the temporal fascia. The temporalis muscle is deep to the fascia and originates in the temporal fossa and inserts into the anterior border of the coronoid process and the anterior border of the ramus of the mandible. See figure 3.1.

5. Section the temporalis muscle where it is attached to the coronoid process of the mandible and pull it away from the mandible.

6. Crack and remove a small piece of the mandible (from the coronoid process to the teeth), in the following steps.

   Crack the mandible horizontally using a chisel to just anterior to the angle of the mandible. Have another person keep the head steady by pushing against the opposite side of the jaw. (This person should be careful not to be cut by jagged bone.)

   Pull away cracked pieces of bone to reveal the inferior alveolar nerve that runs inside the horizontal portion of the mandible.

7. Locate the medial pterygoid muscle deep to where the mandible was. Continue chiseling away the mandible bone along the break to reveal this muscle, taking care not to cut the inferior alveolar nerve. Remove excess fat and fascia, as needed, to reveal the nerve.

8. Locate the following nerves:

   The inferior alveolar nerve runs along the lateral aspect of the medial pterygoid muscle, and enters the mandibular foramen (a circular opening on the ramus of the mandible. The inferior alveolar nerve gives sensation to the teeth and skin of the gums.

   The mylohyoid nerve branches off from the inferior alveolar nerve before the inferior alveolar nerve enters the mandible. The mylohyoid nerve runs along the mylohyoid groove on the medial surface of the mandible.

   The lingual nerve can be found by following the mylohyoid nerve medially from the mandibular foramen. The inferior alveolar nerve and the lingual nerves come from the third branch of the Trigeminal (Fifth Cranial) nerve. The lingual nerve innervates the tongue and inside of the mouth.

   The buccal nerve, a fairly thick nerve, is medial to the lingual nerve.

9. Locate the lateral pterygoid muscle which is approximately parallel to the location of the previously removed zygomatic arch. Note how the lateral pterygoid muscle pulls the jaw forward by pulling on the condyle of the mandible.
10. Section the lateral pterygoid muscle near its insertion at the condyle of the mandible, and then near its origin on the outer side of the lateral pterygoid plate on the skull. Remove the lateral pterygoid muscle.
11. Expose the condyle of the jaw from the surrounding tissue. Attempt to preserve the inferior alveolar and lingual nerves located within these muscles, and trace these nerves up to their exit through the foramen ovale on the underside of the skull.

4. The Neck

Overview and objectives of this dissection

The neck can be thought of as a column or pipe with several smaller pipes inside it. Each pipe is a wall of connective tissue; most structures run superiorly and inferiorly (up and down) inside one particular space between these walls of connective tissue. The outermost column is, of course, the skin. Anteriorly (in the front of the neck), immediately beneath the skin lies the platysma (this muscle will have been exposed by the peeling of the skin in the dissection of the facial regions, because it is thin and inserts into the skin). If you tense the muscles of your neck you can observe your platysma muscles. We will be more concerned with two groups of muscles: the strap muscles of the neck, which lie deep to the platysma muscle, and the muscles forming the floor of the oral cavity, underneath the tongue .

Before beginning the dissection, note the following bony and cartilaginous landmarks, which you should be able to feel on your own neck. It is worth gaining a good understanding of these landmarks before pursuing the dissection because they will be used to locate the muscles in the anterior region of the neck. These locations of these landmarks are illustrated in Figure 4.1. They are also shown in figure 4.3.

The hyoid bone, which lies between the floor of the mouth and the upper end of the neck. Palpate this bone with a thumb and finger on either side of your neck, close to the mandible. You should be able to feel the movements of the cornu (horns) of the hyoid bone by doing the following:

Swallowing.

Saying the vowel sequence [i-a]; noting the higher position of the hyoid bone for the higher vowel.

Saying a single vowel on different pitches. Usually, the higher the pitch, the higher the position of the hyoid bone, though individuals differ in this respect.

The thyroid cartilage, which is the large cartilage of the larynx, forming the major part of the laryngeal prominence (Adam's apple). This will be larger in men than in women. Feel the movements of the thyroid cartilage by repeating the exercises suggested above.

The cricoid cartilage, which is inferior to the thyroid cartilage and sits on top of the first ring of the trachea. Its movements can also be felt by doing the previously suggested exercises.

New Picture
on its way

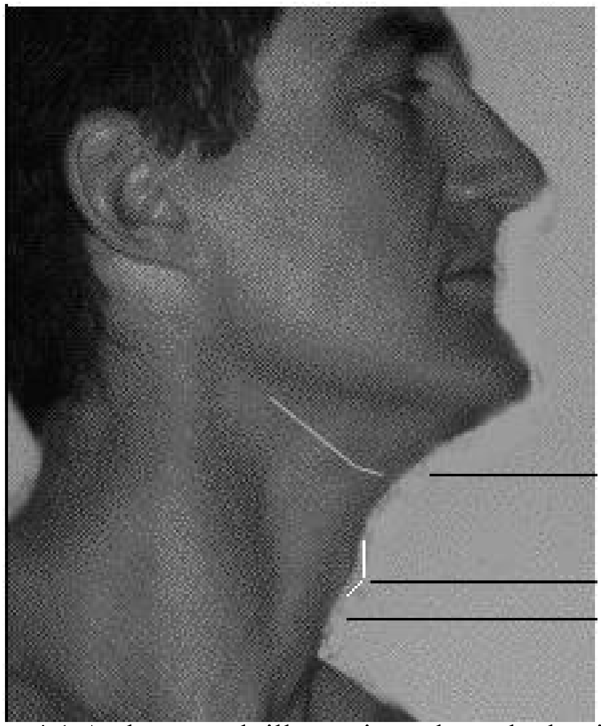


Figure 4.1 A photograph illustrating where the hyoid, thyroid, and cricoid cartilages and the tracheal rings can be felt.

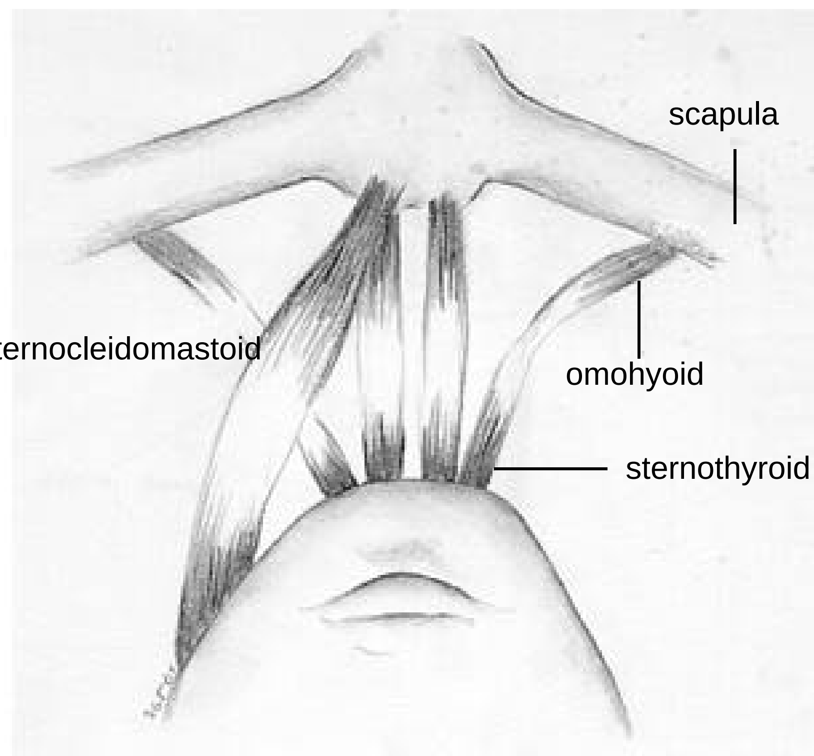
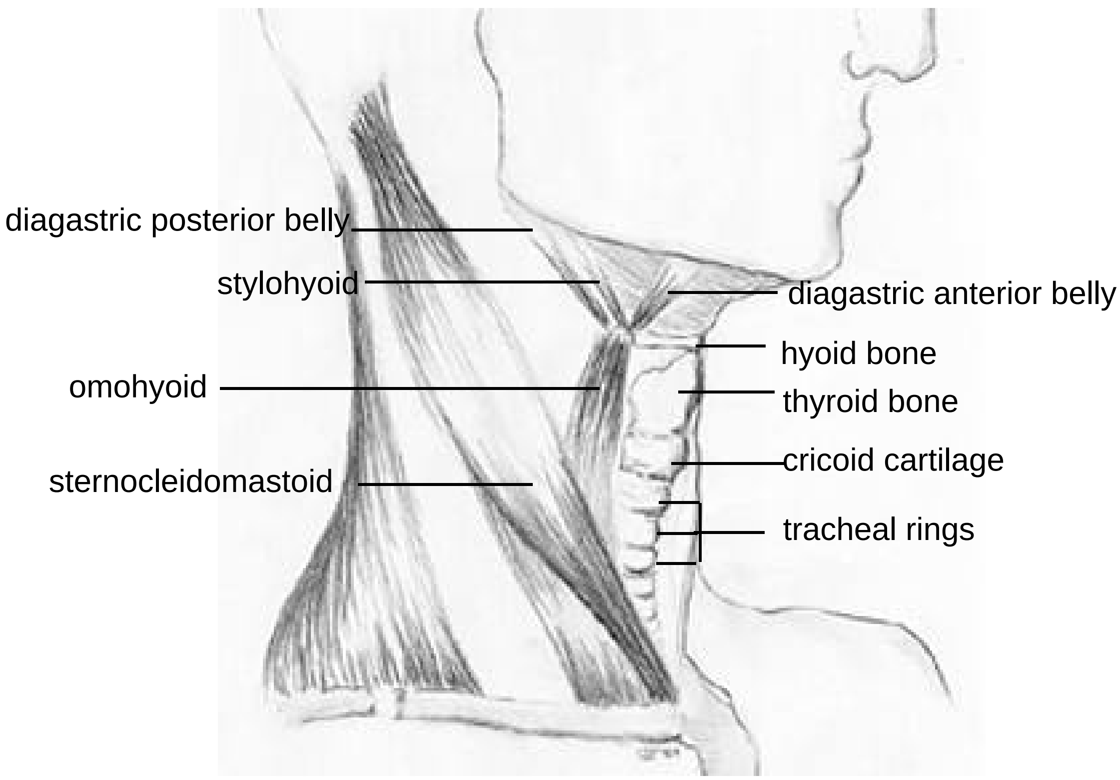


Figure 4.2. The sternocleidomastoid and the outer layer of strap muscles.

The sternocleidomastoid muscle, a major muscle of the neck, runs from the skull just posterior to the angle of the mandible to the sternum (i.e. from your skull to your breastbone). From the point of speech production, more important are the four primary strap muscles, so called because they resemble a barber's strap (used to sharpen blades) or a strap on a horse saddle. They are of concern in speech production in that they control the position of the hyoid bone, and affect the raising and lowering of the larynx. These muscles are located in two layers beneath the platysma muscle and the sternocleidomastoid muscle. The superficial layer consists of two muscles, (1) sternohyoid and (2) omohyoid. These muscles are illustrated in figure 4.2.

The internal layer consists of the two other muscles: (3) thyrohyoid and (4) sternothyroid, which are illustrated in figure 4.3. The superficial strap muscles cover the internal layer of strap muscles.

Figure 4.3. The inner layer of strap muscles and the landmarks of the neck.



After removing all these muscles you will be able to find the recurrent laryngeal nerve, a branch of the vagus nerve, The recurrent laryngeal nerve supplies motor innervation to the intrinsic muscles of the larynx and is thus of prime importance in the production of voiced sounds. If it is injured it is impossible to speak normally. It is called "recurrent" because it starts descending towards the heart, but one branch loops back up to innervate the larynx. The left recurrent laryngeal nerve loops around the aorta, while the right hooks around the right subclavian artery.

The two muscles that form part of the floor of the mouth are the other group of muscles to be investigated. The first, the digastric muscle, consists of two separate bellies (muscle bodies) connected together by a tendon (digastric meaning "two bellies" in Latin). The anterior belly attaches to the mandible anteriorly and runs along the hyoid bone where it passes through a fibrous sling attached to the hyoid. After passing through the sling, the muscle forms the posterior belly, which continues to the medial surface of the mastoid prominence, behind and beneath the ear, Thus it runs downwards from the jaw, through a fibrous sling attached to the hyoid bone, and then back to the skull.

Dissection

The goal of this dissection is to observe the following structures: (1) the strap muscles which control the positioning of the larynx and the nerves responsible for their motor innervation, (2) the larynx and its motor nerves, and (3) the muscles forming the floor of the oral cavity and their motor nerves. It is convenient to dissect these structures from the outside and work inwards, thus starting with the strap muscles and then proceeding to the deeper structures.

1. Reflect the skin from the front of the neck in the following steps:

   First continue the midline incision from the chin down to the clavicle.

   Next reflect back the skin, from the incision line. The platysma, the thin muscle that lies close to the skin, should be removed with the skin at this time.

2. Locate the sternocleidomastoid muscle, which runs from the skull just posterior to the angle of the mandible to the sternum. Find its attachment on the sternum and cut and reflect this muscle laterally from the sternum. This will expose some of the strap muscles of the neck.

3. Locate the two pairs of superficial strap muscles, the sternohyoid and omohyoid. The sternohyoid muscles originate at the back of the joint between the clavicle and the breastbone (the manubrium of the sternum) and inserts into the inferior border of the hyoid bone. Lateral to the sternohyoid muscles are the omohyoid muscles. These muscles originate at the shoulder blades (scapula) and insert into the inferior border of the hyoid bone. Like the digastric muscles discussed below, the omohyoid muscles also have two bellies.

4. Cut and reflect the sternohyoid muscles and omohyoid muscles at their inferior attachments.

5. Locate the two pairs of internal strap muscles, the sternothyroid and the thyrohyoid. The sternothyroid muscles originate at the manubrium and first rib cartilage and insert into the thyroid cartilage.The thyrohyoid muscles originate at the thyroid cartilage and insert into the greater horn of the hyoid bone.

6. Locate the digastric muscle. This muscle consists of two separate bellies (muscle bodies) connected together by a tendon (digastric meaning “two bellies” in Latin). The digastric muscle basically runs from the jaw to the skull. The anterior belly of the digastric attaches to the mandible anteriorly and runs along the hyoid bone where it passes through a fibrous sling, which is attached to the hyoid. The portion of the digastric which passes through the sling is not muscle but tendon. After passing through the sling, the muscle becomes the posterior belly of the digastric which attaches posteriorly to the medial surface of the mastoid prominence, behind and beneath the ear. Note that there is no direct attachment of the digastric muscle to the hyoid bone.

7. Locate the mylohyoid muscle, which is the floor of the oral cavity. The mylohyoid arises from both sides of the inside of the mandible; each side inserting into a midline raphe (a seam-like ridge or furrow joining two different muscles) and joining with the mylohyoid

muscle from the opposite side. The left and right mylohyoid muscles together form a sling which supports the body of the tongue.

8. Section and reflect the sternothyroid muscle along its inferior attachments to reveal the thyroid gland. The thyroid gland consists of two pyramidal lobes joined together by a narrow strip anterior to tracheal rings 2, 3, and 4.
9. Remove the thyroid gland by disconnecting its vascular supply and disconnecting it completely from the trachea.
10. Explore the C-shaped cartilages of the trachea (first note in chapter 1) inserting your finger behind the trachea. The cartilages are joined together by a fibrous elastic membrane. Posteriorly, the gaps in the C-shaped cartilages are closed by smooth muscle, the trachealis muscle. The trachealis muscle rests against the anterior wall of the esophagus.
11. Locate the recurrent laryngeal nerve between the trachea and esophagus. The recurrent laryngeal nerve is a branch of the vagus nerve and supplies motor innervation to the intrinsic muscles of the larynx. The laryngeal nerve is called “recurrent” because it starts descending towards the heart, but one branch loops back up to innervate the larynx. The left recurrent laryngeal nerve loops around the aorta, while the right hooks around the right subclavian artery.

5. The Brain and the Cranial Nerves

Full dissection of the brain is beyond the scope of this manual. We will, however, note the major structures that are important to students of speech as well as the larger structures and landmarks of the brain. The brain is dissected before dissecting the larynx because the orientation of the larynx dissection requires a capless skull.

Working from the outside in, there are three layers of protective tissue, known as **meninges**, which cover the brain, seen in figure 5.1. They are: (1) the **dura mater**, (2) the **arachnoid mater,** and (3) the **pia mater**. The dura mater is a very tough and thick membrane that adheres to the inner surface of the skull. Normally, the dura and arachnoid mater are in very close contact, but after death, the brain may shrink, causing the arachnoid mater to separate away from the dura mater. The arachnoid mater covers the sub-arachnoid space, through which run many of the vessels supplying blood to the surface of the brain. The pia mater is deep to the sub-arachnoid space and separates the sub-arachnoid space from the surface of the brain. The pia mater adheres closely to the entire surface of the brain, running into all its fissures.

(a)

(b)

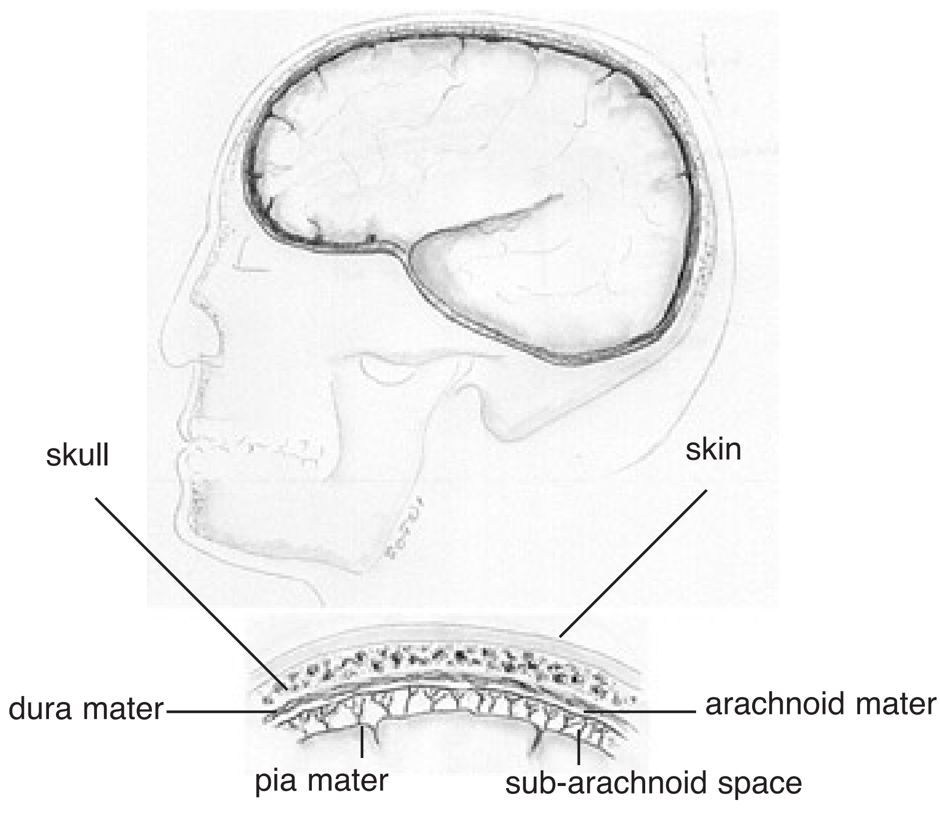


Figure 5.1. (a) The location of the brain; (b) detail of the superior part of the skull, showing the protective layers of the brain, the meninges

The dura mater also delineates the major substructures of the brain with its folds known as **falces** (falx, singular, Latin for 'scythe'). These infoldings of the dura mater cause the brain within the skull to look like half a walnut in its shell. Three of the major falces of the dura mater are: the **falx cerebri**, the **falx cerebelli** and the **tentorium cerebelli**. The falx cerebri and the falx cerebelli divide the brain sagitally (separating left and right); the tentorium cerebelli divides the brain transversely (separating top and bottom).

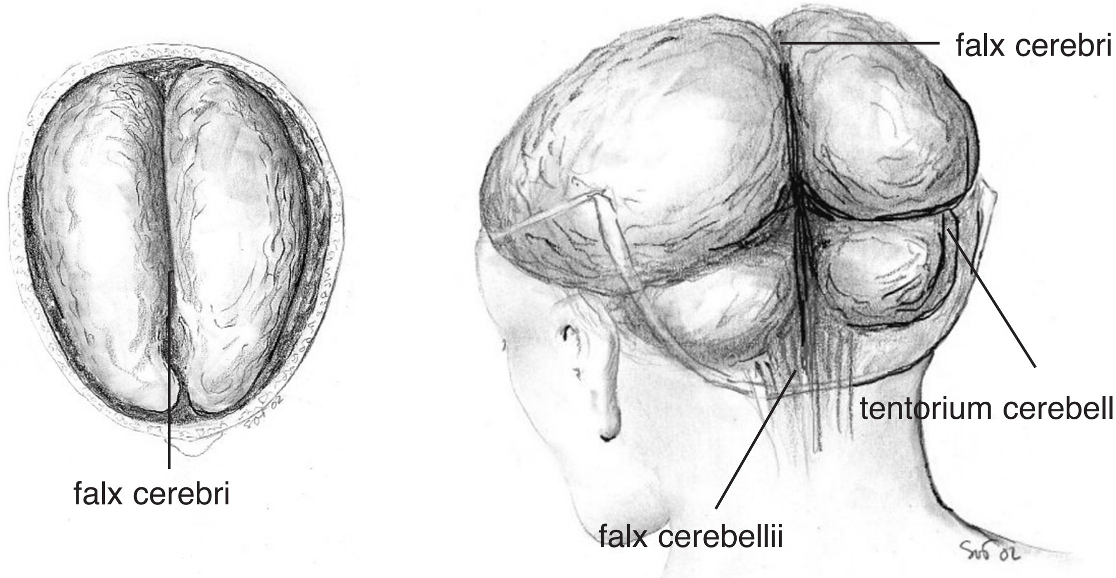


Figure 5.2. The three principal falces of the brain.

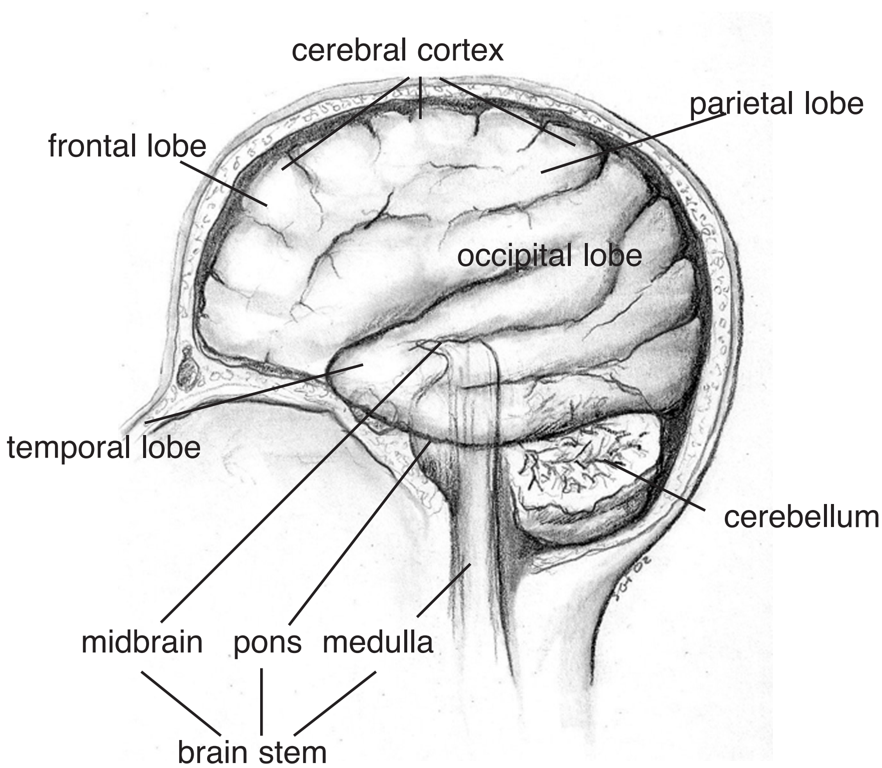


Figure 5.3. Major substructures of the brain.

The brain has several major substructures, some of which are shown in figure 5.3. The **brainstem** is the lowest part of the brain where it connects to the spinal cord. The brainstem may be divided into the **midbrain**, **pons** and **medulla**. The **cerebellum** is the lower back portion of the brain. The **cerebrum** is the main portion of the brain, and what we commonly think of as "the brain". The outer layer of gray matter on the cerebrum is known as the **cerebral cortex**. The brain is divided into two hemispheres, one of which (usually the left) is dominant in the processing of speech. The two hemispheres are connected by a bundle of fibers called the **corpus callosum**. The brain is further divided into six lobes. The four major lobes, named for the bones of the skull with which they are associated, are: the **frontal**, **parietal**, **occipital** and **temporal** lobes. The brain can also be described in terms of its "hills" and "valleys". The hills are called gyri (singular, gyrus) and the valleys that separate the hills are called **sulci** (singular, sulcus). A very deep valley can be called a fissure, although sulcus and fissure are often used interchangeably.

Most of what we know about the function of individual portions of the brain comes from correlating brain damage with dysfunctions in the patient, however the evidence is not always very clear. The skull provides strong protection to the brain, so any blow to the skull strong enough to damage the brain is likely to affect a wide portion of the brain, rather than a single, small area. Similarly, strokes and gunshot wounds generally affect wide areas of the brain. Finally, every brain, like every body, is different from all others. For these reasons, sources disagree about the exact location of the major language centers of the left hemisphere.

Figure 5.4 shows some of the landmarks and structures of interest that we will be pointing out in the dissection guide.

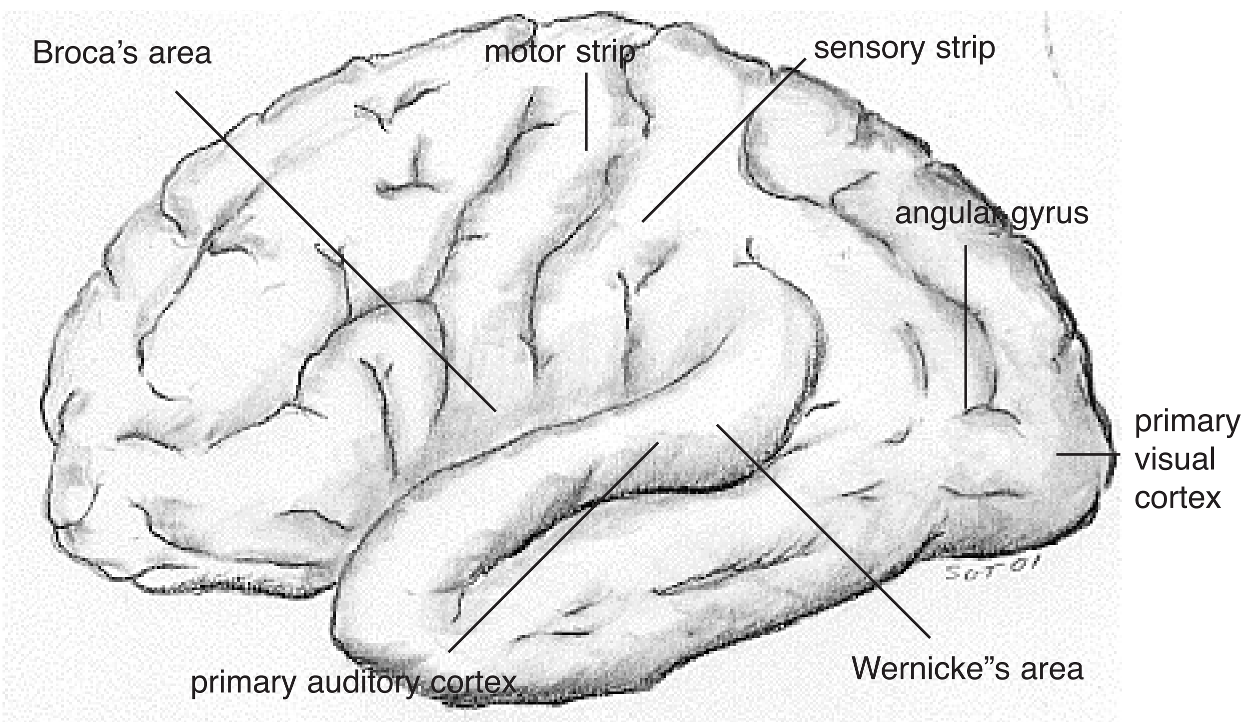


Figure 5.4. Some landmarks and structures of linguistic interest in the brain.

Brocas's area, on the inferior portion of the frontal lobe, is associated with speech production.

Wernicke's area, just below the lateral fissure on the temporal lobe, is associated with speech comprehension.

The **sensory strip**, posterior to the central sulcus, controls the five senses, including hearing.

The **motor strip**, anterior to the central sulcus, controls all muscle movement, including those necessary for speech.

The **angular gyrus**, located in the left temporal lobe, controls speech comprehension and letter recognition.

The **primary auditory cortex,** located in the temporal lobe, processes sounds.

The **primary visual cortex,** located in the occipital lobe, processes visual information. It is important for sign language and visual processing of speech by listeners.

Dissection

Caution: Wear a double set of gloves when handling brain and nervous system tissue. There are viruses which live in the central nervous system that are not killed by formaldehyde or other fixatives. These can be transmitted through cuts or microscopic cracks in your skin. If you cut or puncture your gloves, change them immediately.

1. Removing the scalp

   Prop the head of the cadaver up on a board.

   Make a preliminary incision with a scalpel approximately 1 cm superior to the ears and eyebrows, completely encircling the skull.

   Reflect and remove the area of the skin thus delineated, and remove as much as possible of the osseous membrane below the skin. Removing the membrane will help to keep the saw from slipping when cutting through the skull.

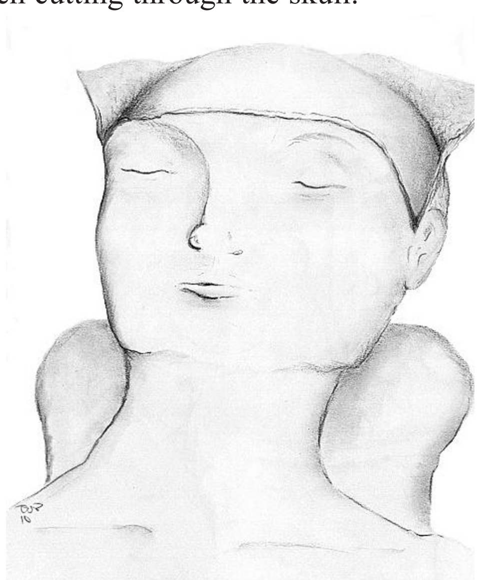


Figure 5.5. Removing the scalp. The head is resting on a block.

2. Removing the skull cap

Mark the skull with a pen along a line just above the incision line that was used to remove the scalp.

Cut along this line with an autopsy saw or a bone saw. Begin by cutting through the frontal bone (the bone at the forehead) laterally to the temporal bone (just above the ear), as illustrated in figure 5.6. Then, turn the cadaver over, and cut from the temporal bone medially through the occipital bone (the bone above the neck).

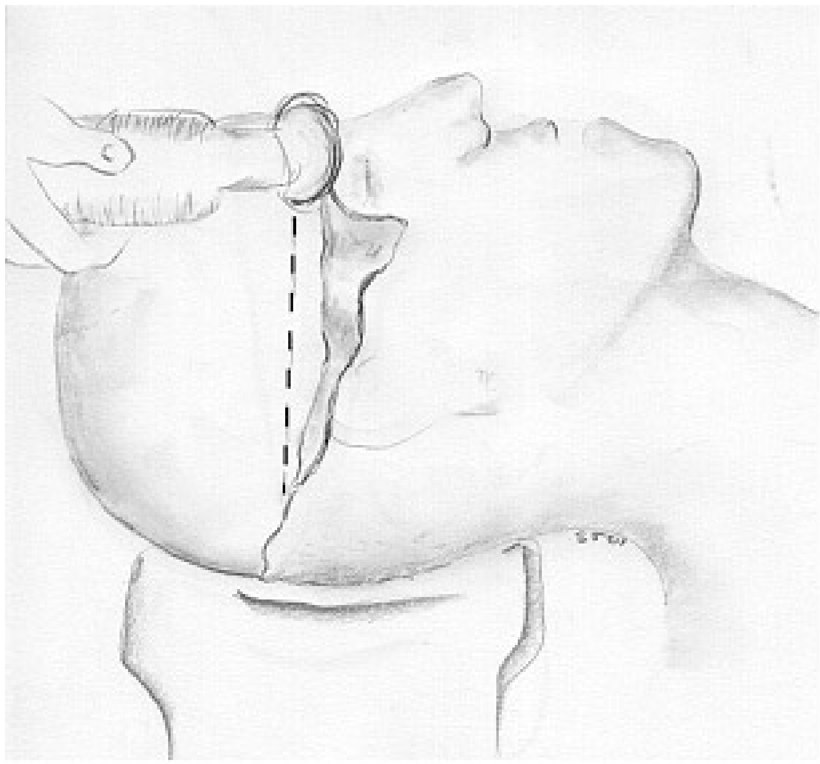


Figure 5.6. Removing the skull cap.

Take a mallet and chisel and remove any last bits of bone tissue that are holding the skullcap on, as shown in figure 5.7

Pry the skullcap free. When you lift the skullcap free, if you have not cut through the dura mater while making the incision, you will probably feel quite a bit of resistance. The dura mater may come off with the skullcap or remain on the brain.

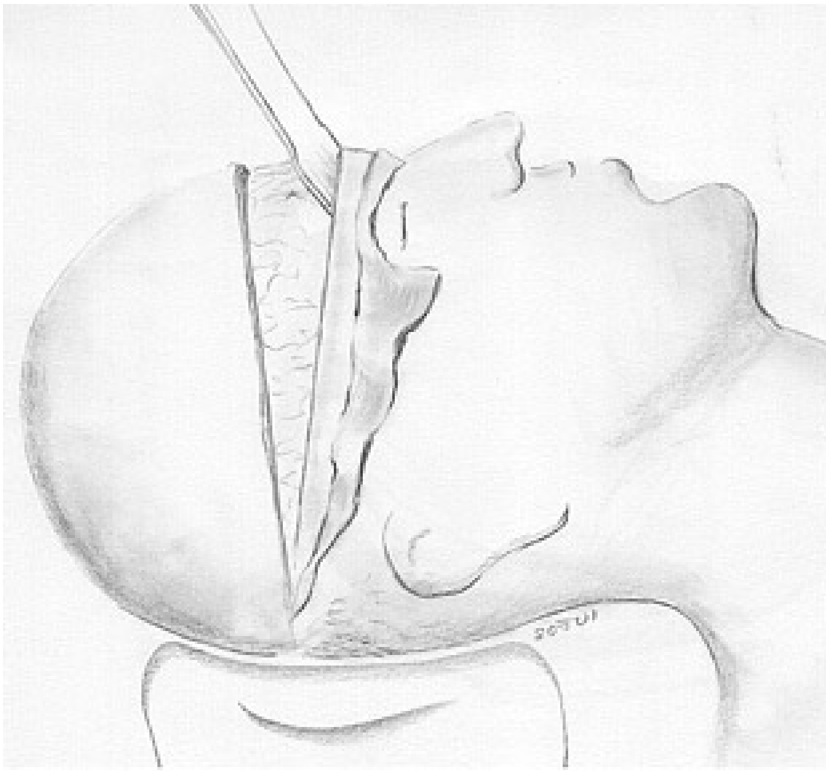


Figure 5.7. Using a chisel to remove the skull cap

3. Removing the meninges

   First remove any remaining dura mater.

   Puncture the dura mater with a scalpel. Then cut through the dura mater with a pair of scissors, following the sectioned edge of the skull cap. Make a complete circle around the opening of the skull (Figure 5.8). Gently lift up one side of the layer of the dura mater and observe the brain inside. At this time, you can observe the arachnoid covering the brain and may be able to see the fissured surface of the brain.

   Determine how well the brain has been fixed. When formalin is pumped into the cadaver, it does not necessarily penetrate all of the extremities. The brain is often insufficiently fixed. If this is the case, it will be soft and pink. To fix an unfixed brain keep it in a container of formalin after it has been removed from the skull.

   If the brain is well-fixed, you may have to remove the arachnoid membrane and some of the blood vessels which run through the sub-arachnoid space in order to better observe the fissures and the sulci of the brain. If the brain is not fixed, the arachnoid and pia mater will be nearly transparent, and it is best to leave them intact.

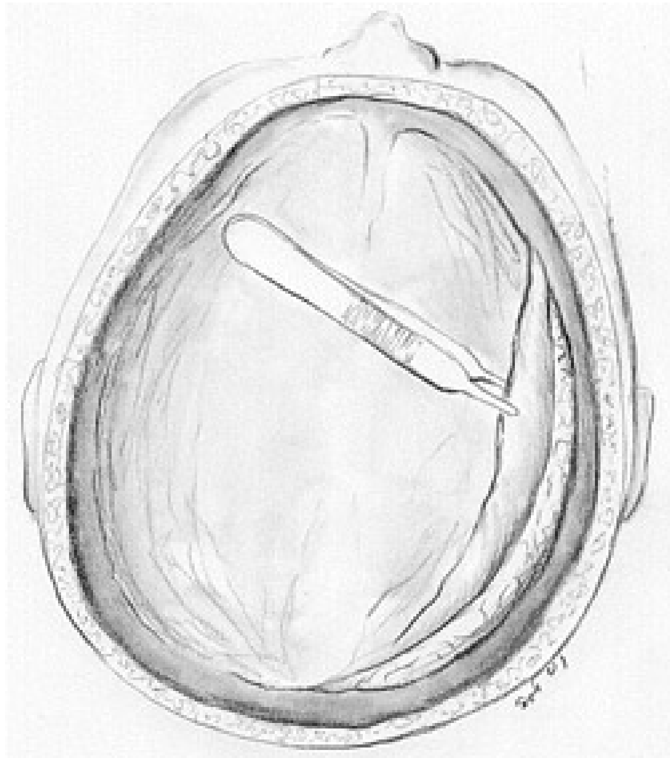


Figure 5.8. Incision and reflection of the dura mater.

4. Observing the general structure of the brain

   Locate the interhemispheric fissure, or longitudinal fissure, which separates the right and left hemispheres. Within the interhemispheric fissure is an extension of the dura mater called the falx cerebri.

   Reflect back the falx cerebri at its anteroinferior border (near the forehead) with a a scalpel. This is only necessary to do if the dura mater has remained attached to the brain.

5. Removing the occipital bone

   Remove a trapezoidal wedge of skin from the occiput (the back of the skull), starting four or five centimeters posterior to the ear and extending downward one or two centimeters past the base of the neck to a point about three centimeters lateral to the mid-line on both sides. The object is to allow you to remove part of the bone as shown in figure 5.9

   Remove as much of the fatty and muscular tissue from this area as possible. This will make it easier to cut the bone

   Cut from the edge of the open skull to the foramen magnum (the large hole containing the spinal cord) with an autopsy saw. Pry off the wedge of occipital bonewith a chisel, detaching it from the dura mater underneath.

   Locate the tentorium cerebelli, the fold of dura mater that projects horizontally between the occipital lobes of the cerebrum and the cerebellum. Cut and remove the tentorium cerebelli. Observe the finely fissured lobes of the cerebellum underneath it. Note the different texture of the tissue of the cerebellum, compared to the cerebrum.

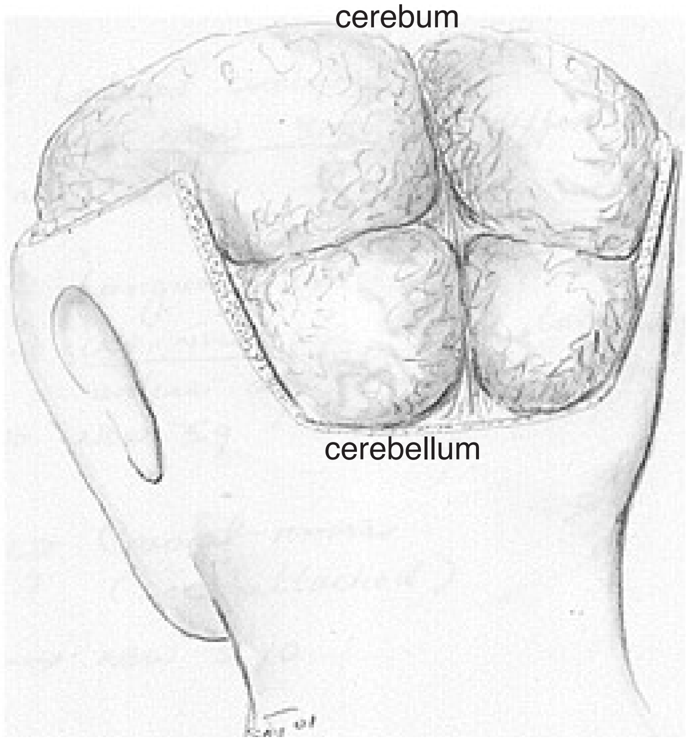


Figure 5.9. Trapezoidal excision to expose the posterior brain..

Locate the falx cerebelli between the two lobes of the cerebellum and remove them.

At this point you should have removed all the dural reflections of the brain, so that it looks somewhat like a half walnut in its shell. Look carefully at the brain as it sits in the cranial cavity. Observe the lobes of the brain and how the cranial cavity envelopes it in a bony protective case.

6. Cutting the spinal cord and removing the brain

   Locate the top of the spinal cord in the foramen magnum. Use a sharp scalpel blade to cut through the spinal cord at the lowest possible level down the neck, making sure that you cut the arteries that surround the spinal column, as well.

   Locate the frontal lobes of the brain.

   Lift the frontal lobes up from the front out of the skull, carefully and slowly. Take your time and gently pull the brain backwards, while cutting all the cranial nerves and arteries that are resisting your pull. If you do not cut them, the brain will tear as you reflect it backwards. Attempt to identify each of the cranial nerves as you cut it. Once you have severed all the arteries and nerves, the entire brain should pull free.

   Remove the brain and observe the empty cranial cavity. The cranial cavity is composed of three major fossae (shallow depressions; Latin ‘ditch’):

   the anterior fossa supports the frontal lobe;

   the middle fossa supports the temporal lobe the posterior fossa supports the cerebellum,

Observe how the three fronal lobes sit in the their respective cranial fossae.

7. Locating structures of linguistic interest in the brain

Hold the brain with gloved hands and spend a moment gently exploring the various lobes, gyri and fissures with your fingers. Compare what you see with figures 5,2. 5.3 and 5.4.

Locate the lateral fissure and central sulcus. These may be more or less difficult to identify depending on the brain. The lateral fissure is the most prominent horizontal fissure on either hemisphere. The central sulcus is the most prominent vertical fissure extending superiorly from the lateral fissure.

Identify the frontal, parietal, temporal, and occipital lobes. Use the lateral fissure and the central sulcus to help pick out these particular lobes. The lateral fissure is the fissure that separates the temporal from the parietal and frontal lobes.

Gently separate the two hemispheres and look into the longitudinal fissure. Within the fissure is the corpus callosum, a large bundle of fibers which connects the two sides of the brain.

Locate the following structures and landmarks in the brain:

The motor strip on the frontal lobe just anterior to the central sulcus.

The sensory strip, just posterior to the central sulcus on the parietal lobe. Most of the motor control and sensory input for one side of the body is mediated by activity in the associated gyrus on the opposite side of the brain.

Broca's area on the inferior frontal gyrus just in front of the motor strip.

The primary auditory cortex on both hemispheres of the brain. The primary auditory cortex consists of the gyri on the superior portion of the temporal lobe, just below the lateral fissure.

Wernicke's area on the left hemisphere. Wernicke's area is part of the auditory cortex in the posterior region of the temporal lobe.

The occipital lobe on the posterior aspect of the brain. The occipital lobe and related structures are not as clearly delineated by anatomical landmarks as the other lobes and areas of the brain, so location is likely to be approximate.

The primary visual cortex on the posterior portion of the occipital lobe, at the very back of the brain.

The angular gyrus located on the anterior portion of the occipital lobe.

Locating the nerves

There are twelve cranial nerves which exit from the brainstem (figure 5.10). The cranial nerves relevant to speech are the fifth (trigeminal), seventh (facial), eighth (vestibulocochlear), ninth (glossopharyngeal), tenth (vagus), and twelfth (hypoglossal). Depending on the cadaver, it

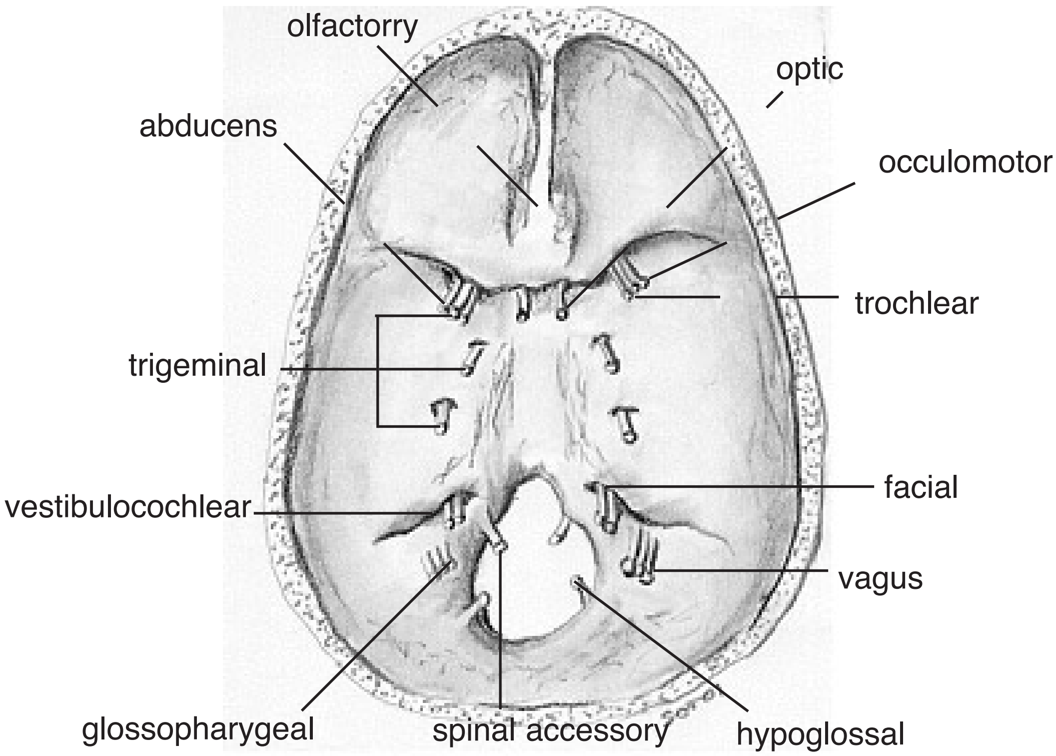


Figure 5.10. The cranial nerves and associated foramina, as seen within the skull cavity (brain removed and cranial nerves severed, superior view). Nerves not relevant to speech are indicated with dotted lines.

may be easier to locate some of the nerves on the brain and some of them on the interior surface of the skull. The two easiest nerves to locate are not speech related, the first (olfactory) and the second (optic). Use them as reference points for locating the other nerves.

Table of Cranial Nerves and Their Functions

(nerves relevant to speech in bold)

Number	Name	Function
I	Olfactory	Smell.
II	Optic	Vision.
III	Oculomotor	Motor control to extraocular muscles (controls eye movements).
IV	Trochlear	Motor control to extraocular muscles (controls eye movements).
V	**Trigeminal**	Sensory connections to face, soft and hard palate, nasopharynx, and anterior 2/3 of tongue. Motor connections to lateral and medial pterygoid, temporalis, masseter, anterior belly of digastric, mylohyoid and tensor palatini.
VI	Abducens	Motor control to extraocular muscles (controls eye movements).
VII	**Facial**	Sensory connections to taste from anterior 2/3 of tongue. Motor control to muscles of facial expression, posterior belly of digastric and stylohyoid.
VIII	**Vestibulocochlear**	Hearing and balance.
IX	**Glossopharyngeal**	General sensory and taste sensation from posterior 1/3 of tongue. Motor control to stylopha- ryngeus.
X	**Vagus**	General sensory from pharynx and larynx. Motor control to cricothyroid, levator palatini, pal- atoglossus, palatopharyngeus, salpingopharyngeus and all intrinsic muscles of the larynx.
XI	Spinal accessory	Motor control to sternocleidomastoid and trapezius.
XII	**Hypoglossal**	Motor control to genioglossus, styloglossus, hyoglossus and intrinsic muscles of the tongue.

6. The Pharynx

The pharynx, which forms the upper part of the digestive tract, consists of three parts: the nasopharynx, the oropharynx and the laryngopharynx. The principle object of this dissection is to observe the pharyngeal constrictors that form the back wall of the vocal tract. Because the cadaver is lying face down, we will consider these muscles from the back. Figure 6.1 shows their location.

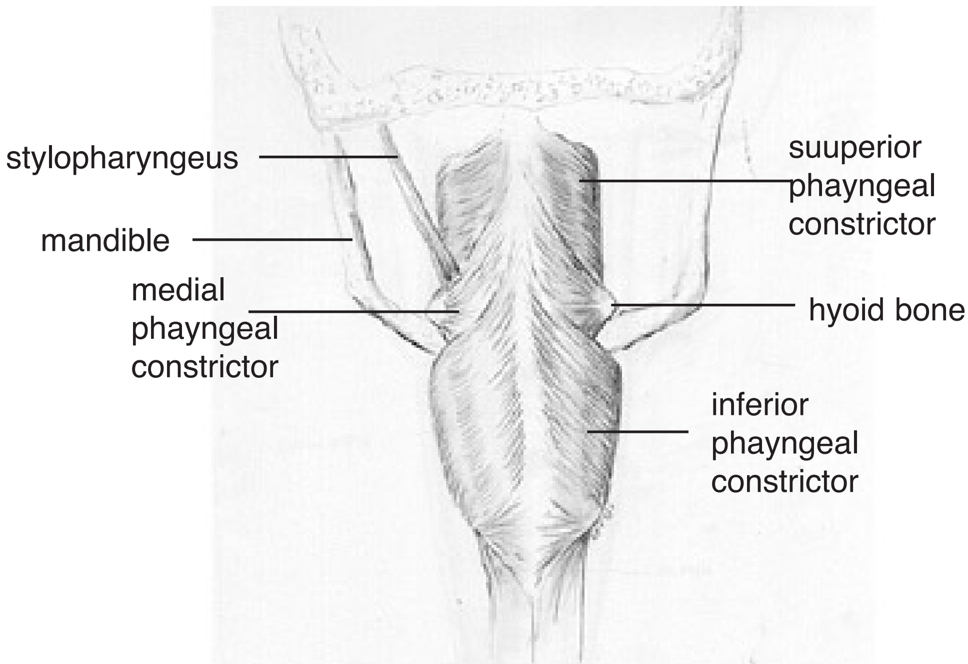


Figure 6.1. Posterior view of the muscles of the pharynx.

Each of the three pharyngeal constrictors has a left and right part that interdigitate (join in fingerlike branches) in the midline, forming a raphe, or union. This raphe forms the back wall of the pharynx. The superior pharyngeal constrictor is largely in the nasopharynx. It has several origins (some texts regard it as more than one muscle) one of which is the medial pterygoid plate. It assists in the constriction of the nasopharynx, but has little role in speech production other than helping form a site against which the velum may be pulled when forming a velic closure. The medial pharyngeal constrictor, which originates on the greater horn of the hyoid bone, also has little function in speech. To some extent it can be considered as an elevator of the hyoid bone, but its most important role for speech is simply as the back wall of the vocal tract. The inferior pharyngeal constrictor also performs this function, but plays a more important role constricting the pharynx in the formation of pharyngeal consonants. It originates on the thyroid cartilage, with some additional fibers arising from the cricoid cartilage. These two parts are sometimes called the thyropharyngeus and the cricopharyngeus muscles.

Before proceeding with the dissection, you should also review the structures found in previous dissections. By palpation on the cadaver (and on yourself), locate the hyoid bone, the anterior aspect (front side) of the thyrohyoid membrane, the superior (top) border of the thyroid cartilage and its superior cornu (horn). Notice the thyroid notch in the midline. You should be able to locate all these features on yourself. Below the thyroid notch, on the cadaver, locate the cricothyroid muscle which connects the cricoid cartilage (the first cartilage ring of the trachea) to the thyroid cartilage. Posteriorly (in the back), the recurrent laryngeal nerve can be seen adjacent to the joint of the cricoid and the thyroid cartilage.

Dissection

Caution: In this dissection, you will cut through the spinal column. As always when dealing with central nervous system tissue, wear double gloves.

This dissection consists of three parts. First, we will cut through the spinal column and the adjoining musculature. This will sever the head and neck from the torso. Next we will locate the pharyngeal muscles. Finally we will open up the pharynx to reveal the larynx and its structures.

1. Locate the retropharyngeal space and work a probe into it, separating the two layers of fascia (Figure 6.2). Enlarge the space by moving the probe up and down. This will isolate the structures we wish to preserve from those we will simply cut through.

   The retropharyngeal space is a region between two layers of fascia separating the spinal column from the esophagus and trachea. The pretracheal fascia encloses the organs in the anterior portion of the neck, and the prevertebral fascia encloses the spine and its musculature. Between these two fascia lies the retropharyngeal space, the space between the esophagus and the spinal cord.

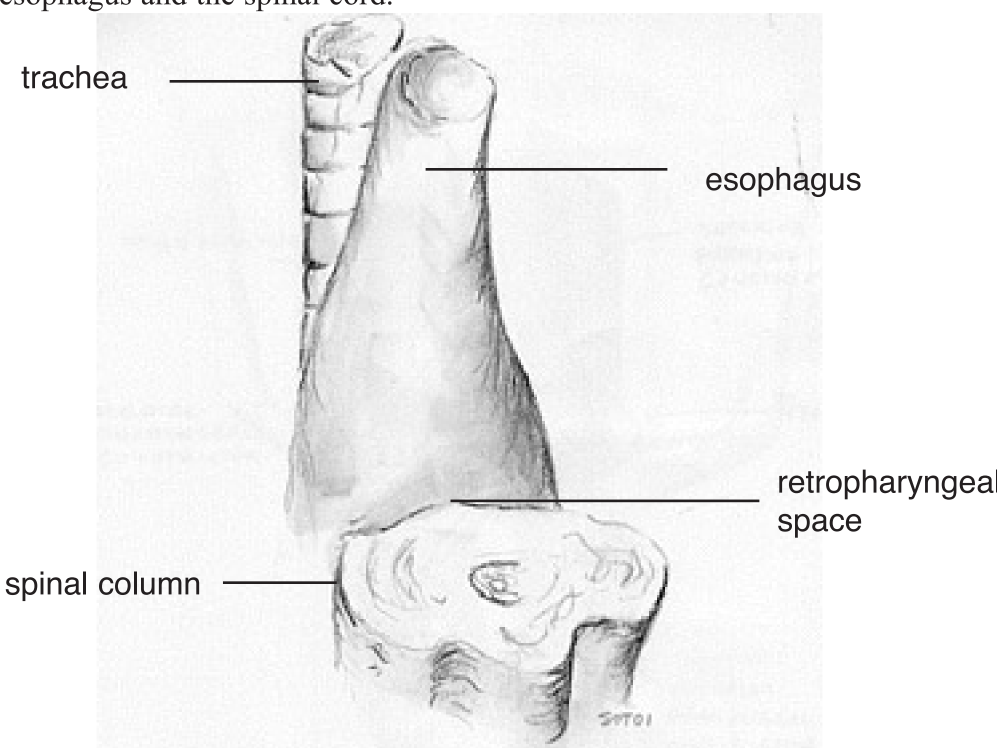


Figure 6.2. The retropharyngeal space, as seen from the rear.

2. Turn the cadaver over to a prone position (i.e. face down) with the probe in place. .

3. Sever the muscles attached to the cranium and clear away all the muscles along the back and sides of the neck. From the back you should now see the cervical vertebrae.

4. Cut transversely with a bone saw through the spinal column at a level anywhere between cervical vertebrae C1 and C4, C1 being the first vertebra in the spinal column.

5. Sever all the prevertebral muscles with a sharp scalpel down to the level of the probe in the retropharyngeal space. The prevertebral muscles run between the front of the vertebrae to the occipital bone or the ribs.

6. Turn the cadaver over once more so it is now supine (i.e. face up).

7. Cut the trachea and esophagus as close to the clavicle as possible. The head is now severed from the body, and you can discard the lower portion of the cadaver at this stage. (Please confirm what the disposal rules are before doing this.)

8. Put the severed head face down on the table with the cut skull resting flat, so that you are viewing the pharynx from the posterioinferior view (from behind and below). Because the head is now upside down, it is important to remember that all vertical directions in this section are given in relation to the cadaver in an upright position. Locate the styloid process by inserting your finger in the cavity behind the ear.

The Pharynx

1. The superior constrictor muscle

   Remove the medial pterygoid muscle to uncover the superior constrictor muscle of the pharynx. The medial pterygoid muscle is attached to the medial pterygoid plate. The medial pterygoid plate and the lateral pterygoid plates look like wings and extend out from the sphenoid bone. The sphenoid bone is located on the skull just behind the eyes and nose. The pterygoid plates are not yet visible at this stage of the dissection, and they may be broken off of a skull model.

   Observe the raphe joining the two halves of the superior constrictor muscle.

   Observe how the superior part of the pharynx relates to its surrounding structures. Note how the constrictor muscles of the pharynx and the buccinator muscle of the cheek form a contiguous wall and enclose the oropharyngeal cavity. Underneath the superior constrictor muscle, the back wall of the pharynx consists of the pharyngobasilar fascia which is attached to the skull base. The upper edge of this fascia lies level with the hard palate. The pharyngotympanic (eustachian) tube passes through the space between superior constrictor muscle and base of the skull.

2. The medial constrictor muscle

   Locate the medial constrictor muscle. It arises from the horns of the hyoid bone and attaches to the median raphe of the superior constrictor muscle. The medial and inferior constrictor muscles are divided by the thyrohyoid membrane, which is attached to the thyroid cartilage and the hyoid bone.

3. The inferior constrictor muscle

   Locate the inferior constrictor muscle. It is composed of two distinct parts, the thyropharyngeus and the cricopharyngeus muscles. The thyropharyngeus muscle is attached anteriorly to the oblique line (a vertical line on the side) of the thyroid cartilage and from there sweeps posteriorly to the midline raphe. Superiorly, it is attached as high as the level of the soft palate. Inferiorly, its lowermost fibers are horizontal and adjacent to the cricopharyngeus muscle. The cricopharyngeus muscle is attached from one side of the cricoid arch to the other. Thus, there is no midline raphe. The cricopharyngeus muscle is a sphincter muscle at the lower end of the pharynx, and opens only during the act of swallowing.

Opening the pharyngeal cavity

1. There are two methods for opening the pharyngeal cavity:

   Locate the superior horns of the thyroid cartilage and the greater horn of the hyoid bone. With a sharp scalpel, make an incision between these two landmarks from left to right. From the mid-line of this first incision, cut vertically through the posterior wall of the pharynx, inferiorly to the superior edge of the esophagus.

   Alternatively, dissect from the inferior, cut edge of the esophagus up to the hyoid bone. Next, make a horizontal incision between the horns of the thyroid cartilage and the greater horns of the hyoid bone.

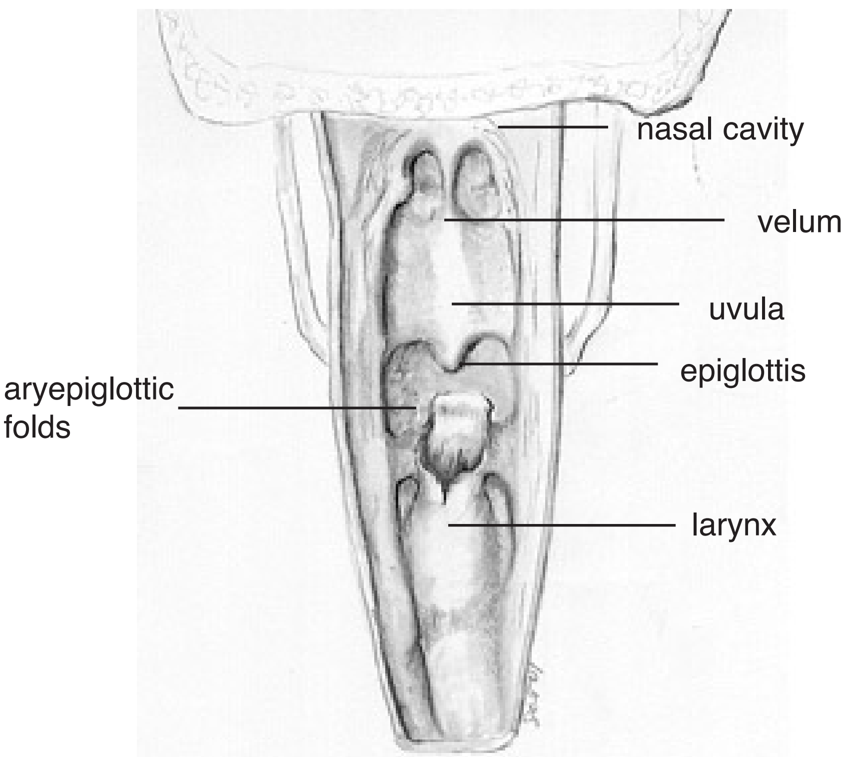


Figure 6.3. The opened pharynx from behind. Note that the posterior musculature of the larynx is still covered with fascia.

2. Reflect laterally the flaps of the pharyngeal wall thus formed.
3. Shine a light down the tube of the larynx to see the vocal cords forming a V-shaped opening with the apex of the V pointing anteriorly. The vocal folds may be smaller than expected, and difficult to see.
4. Locate the epiglottis. It is a leaf-shaped structure, which is attached by a stalk to the midline of the posterior aspect of the thyroid cartilage. Food goes around the epiglottis through the periform sinuses into the esophagus.
5. Locate the aryepiglottic folds. They run inferoposteriorly along the side of the epiglottis toward the arytenoid cartilages. The aryepiglottic muscles, which lie beneath the mucosa covering these folds, attach to the arytenoid cartilage.
6. Locate the arytenoid cartilages. (Although they cannot be seen in the figure, they can be palpated.) These triangulate cartilages sit on the cricoid cartilage. The arytenoid cartilages are covered posteriorly by the arytenoid muscles.
7. Locate the corniculate cartilages (also not shown on the figure) on the apex of each arytenoid cartilage. These are best found by gently palpating the arytenoid cartilages.

7. The Tongue

This portion of the dissection will concentrate on the muscles of the tongue. These muscles are divided into extrinsic (originating outside the tongue) and intrinsic (situated within the tongue) muscles. First, we examine the attachments of the tongue's extrinsic muscles and attempt to understand how they serve to move and shape the tongue during speech. Then, we bisect the tongue and excise one half This will allow us to examine the tongue's intrinsic muscles and how they serve to move and shape the tongue during speech.

The four major extrinsic muscles of the tongue are shown in figure 7.1:

The mylohyoid muscle, which is responsible for raising the body of the tongue in high vowels and velar consonants.

The hyoglossus, which pulls it downwards (and slightly backwards).

The styloglossus, which pulls the tongue upwards and backwards.

The genioglossus, which forms the bulk of the inferior part of the tongue and pulls the body of the tongue forwards.

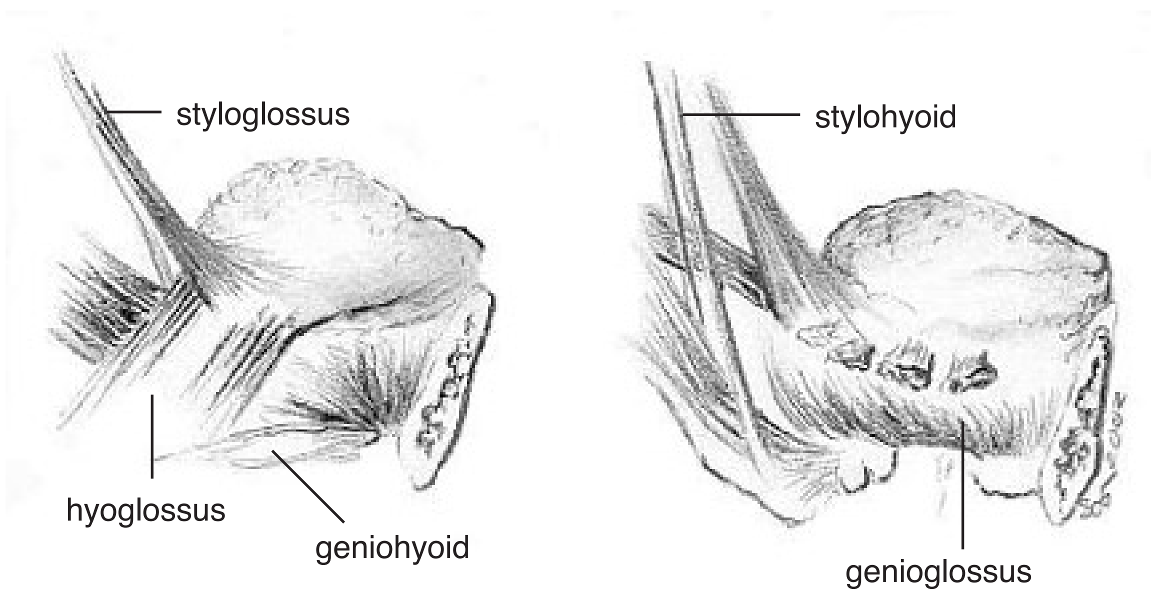


Figure 7.1. The extrinsic muscles of the tongue.

We have already observed the mylohyoid muscle in Section 4. It forms the floor of the mouth and controls the raising of the tongue. It is also an elevator of the hyoid bone, and hence elevates the larynx. The hyoglossus is a broad, flat muscle running from the greater horn of the hyoid to the posteroinferior lateral aspects of the tongue (on the sides of the lower back of the tongue). It is a depressor (lowerer) of the tongue. The styloglossus extends from the styloid process, a projection of the skull at about the level of the ear down into the lateral aspect of the tongue, interdigitating with the inserting fibers of the hyoglossus. The genioglossus is attached to a point on the mandible about halfway between the chin and the lower incisors (front teeth). (Check by feeling with a forefinger down behind the lower front teeth in your own mouth, and noting where this muscle attaches.) From this point, the muscle fibers fan out posteriorly and superiorly (backwards and upwards) to form the inferior portion of the tongue.

In addition to these four muscles, we will also note two other muscles. The first is the palatoglossus muscle, a small muscle that can assist the action of the styloglossus. The palatoglossus muscle can be found on the posterolateral (back, side) aspect of the tongue below the mucous membrane of the anterior faucal pillar (located on the walls of the mouth on either side of the uvula). From the undersurface of the soft palate, this muscle curves inferiorly (downwards) to insert into the side of the tongue. The second muscle is the palatopharyngeus muscle, which forms the posterior faucal pillars. It does not affect the position of the tongue. The palatoglossus is innervated by the vagus nerve (the Xth), whereas all the other tongue muscles are innervated by the hypoglossal nerve (the X11th).

The intrinsic muscles of the tongue that we will examine are shown in figure 7.2:

The superior longitudinal muscle, with fibers that run anteroposteriorly (from the front to the back) along the superior surface of the tongue, just below the mucous membrane.

The inferior longitudinal muscle, with fibers that run along the sides of the tongue, from the root to the tip of the tongue. Anteriorly (to the front) these fibers join those of the styloglossus muscle.

The verticalis muscle, with fibers that arise near the midline of the superior surface of the tongue and course inferolaterally (down and to the sides) to insert into the sides of the tongue.

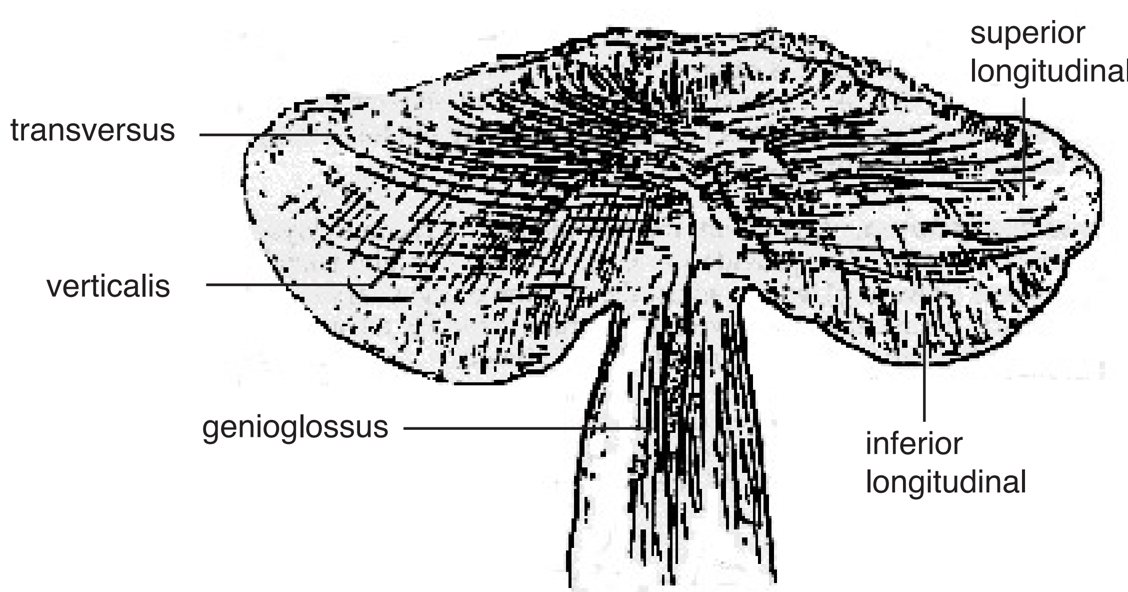


Figure 7.2. A coronal section of the tongue. Note the complexity of the intertwined muscle fibers. (Based on Abd-el-Malek (1939); for another view drawn during a dissection, see figure 7.6.)

The transversalis muscle, with fibers that extend from the mucous membrane on the sides of the tongue to the median septum, which divides the tongue in half saggitally (down the midline).

The actions of some of the muscles of the tongue are summarized in Figure 7.3.

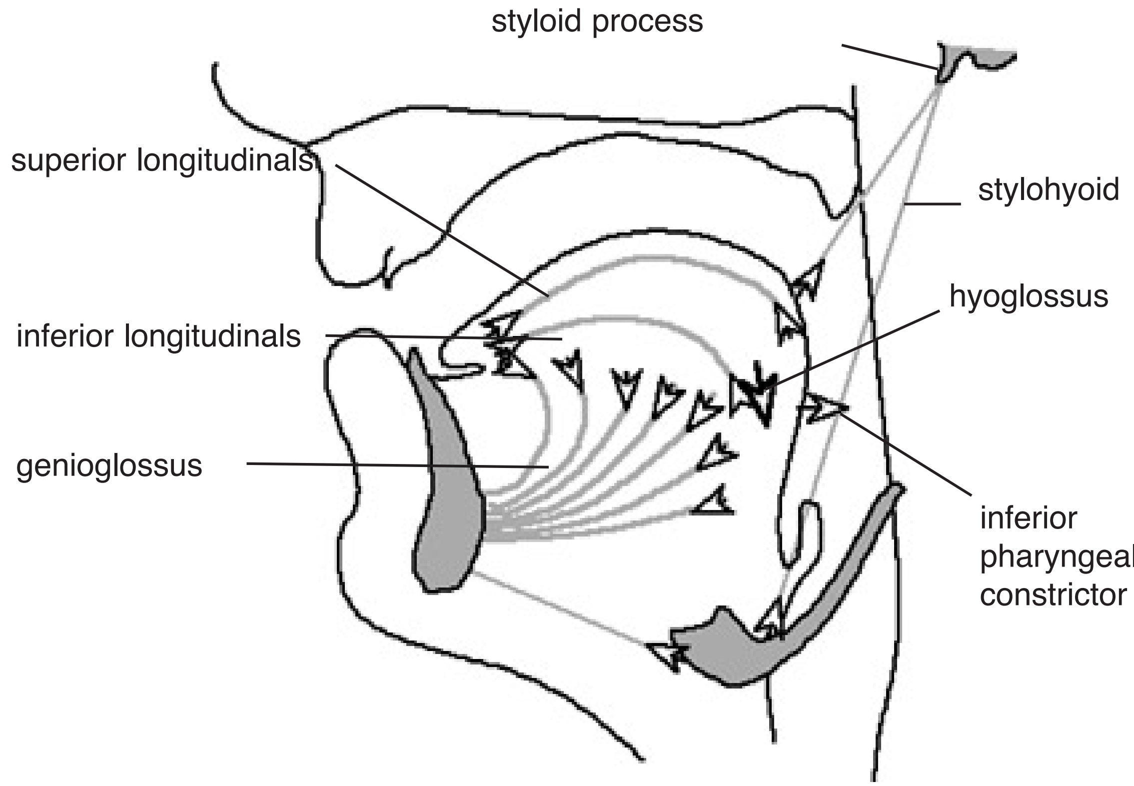


Figure 7.3. Schematic diagram of the actions of some of the muscles of the tongue.

Dissection

This dissection will consist of two parts, first exposing and dissecting the extrinsic muscles of the tongue, and then exploring the intrinsic muscles. Before beginning you should identify structures on the tongue service..

papillae (bumps on the tongue)

foramen caecum (the little pouch on the root of the tongue)

frenulum (the connective tissue between the underside of the body of the tongue and the mylohyoid muscle)

valleculae (two shallow oval pits formed by the membrane between the tongue and the epiglottis; food passes through them)

In order to fully examine the extrinsic muscles of the tongue, the dissection must be done from two separate directions. The mylohyoid, hyoglossus and genioglossus muscles will be exposed from below. The styloglossus will be exposed from behind.

Dissecting the tongue from underneath (figure 7.4)

1. Cut the right and left anterior bellies of the digastric as close as possible to the mandible. (This muscle was discussed in chapter 4; see figure 4.3.)

2. Reflect both bellies of the digastric muscle down towards the hyoid bone.

3. Clean away all fat from the mylohyoid muscle and remove the rest of the submandibular gland. Note that the mylohyoid originates from the myloid (interior) ridge of the mandible on each side and meets at its midline raphe. The mylohyoid muscle then inserts at the anterior part of the hyoid bone. Find the posterior border of the mylohyoid muscle and locate the origin of the hyoglossus muscle near this point.

4. Section and reflect the hyoglossus at its superior attachment, revealing the tongue.

New figure to come

Figure 7.4. Dissection of the tongue from below

Exposing the extrinsic muscles of the tongue from behind

1. Turn the head of the cadaver over so you are now approaching it from the posterior aspect of the neck.

2. Locate the part of the stylopharyngeus muscle (figure 6.1) where it passes between the medial and superior pharyngeal constrictors and separate it from the surrounding tissue. Clean up toward the styloid process.

3. Locate the lower end of the stylohyoid muscle (figutr 4.3) where it wraps around the tendon of the digastric muscle just above the hyoid bone. Follow the stylohyoid muscle up to the styloid process, just behind the ear.

4. Locate the styloglossus muscle beneath the stylopharyngeus and stylohyoid.

Exposing the side of the tongue

1. Turn to the side of the head where the mandible has already been opened during the dissection of the jaw (figure 7.5).
2. Cut and remove a small piece of the mandible below the coronoid process and above the angle of the mandible. Locate the styloglossus muscle. Locate the inferior alveolar nerve, on the inside of the mandible.
3. Sever the mylohyoid muscle close to the mandible, if you have not done so already, and reflect it medially and inferiorally.
4. Locate the styloglossus and hyoglossus muscles beneath the severed mylohyoid muscle. Some fibers of the styloglossus may form a raphe or interdigitate with the hyoglossus; other fibers may pass superficially over the hyoglossus and enter the tongue.
5. Locate the visible portions of the genioglossus and the geniohyoid.

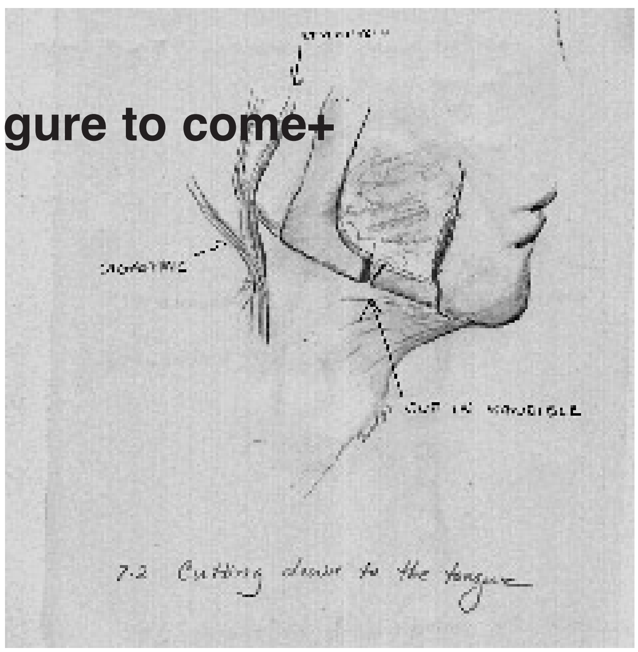


Figure 7.5, Exposing the side of the tongue

6. Detach the mylohyoid muscle from the hyoid bone, completely exposing the geniohyoid muscle.
7. Detach the geniohyoid muscle from the genioid process (the chin), and reflect it inferiorly.
8. Locate the paired genioglossus muscles on the interior of the mandible at the chin. Locate the course of the inferior fibers of the genioglossus. A small group of inferior and lateral fibers of this muscle attach to the hyoid bone. Follow the fibers of the inferior surface of the genioglossus muscle down medially, deep to the hyoid bone, and observe how they insert into the root of the epiglottis.

9. Insert a probe along the inferior aspect of the genioglossus, between the genioglossus and the geniohyoid. Then, posteriorly (i.e. from within the pharynx, from the back) feel the tip of the probe in the neighborhood of the epiglottis. This will clarify the relation of the genioglossus and the epiglottis.

10. Detach the hyoglossus from the hyoid bone, and reflect it superiorly, revealing the parts of the styloglossus muscle which pass deep to the hyoglossus and enter the inferior part of the tongue.

11. Locate the fibers of the genioglossus muscle that pass lateral to the stylopharyngeus muscle and insert into the medial pharyngeal constrictor muscle.

The palatoglossus muscle

Locate the palatoglossus muscle. The palatoglossus muscle forms the anterior portion of the arch from which the uvula hangs, known as the pillar of the fauces. From the undersurface of the soft palate, the palatoglossus curves downward to insert into the side of the tongue. The posterior portion of the pillar of the fauces is formed by the palatopharyngeus muscle.

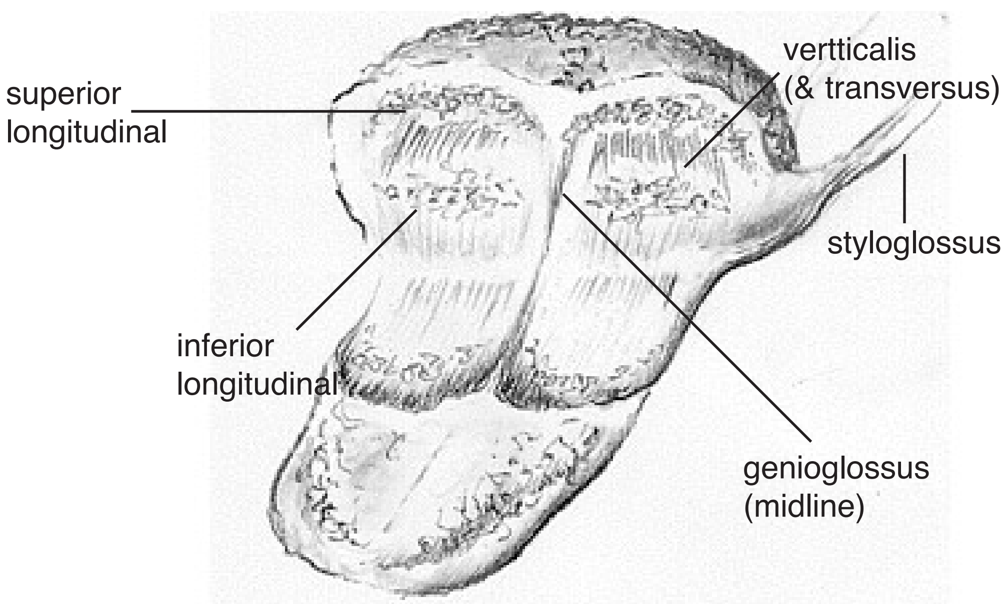


Figure 7.6 A coronal section of the tongue (for a whole tongue, rather than just one half) viewed from behind.

The intrinsic muscles of the tongue

Note: it is very difficult to distinguish all these muscles

1. Bisect the tongue with a sharp scalpel just lateral to the midline, revealing a mid-sagital section of the tongue.

2. Observe the fanning out of the genioglossus muscle on the sectioned edge.

3. Locate the superior longitudinal muscle in the region of the tongue tip. These muscle fibers

run slightly below the surface of the tongue through its entire length. They fan out from posterior to anterior to attach to the mucous membrane of the tongue. The most inferior fibers attach to the body of the hyoid bone.

4. Remove one of the halves of the tongue from the mouth by cutting as close to its lower attachments as possible.
5. Cut the excised half of the tongue coronally into successive slices.
6. Locate the transversus muscle fibers in the sections. The fibers of the transversus muscles originate near the median fibrous septum of the tongue and run laterally to insert into the muscles of the side of the tongue, i.e. they run transversely.
7. Locate the verticalis muscle fibers in the sections from the forepart of the tongue. These fibers run superoinferiorally, i.e. vertically.
8. Remove the skin from the underside of the half of the tongue remaining in the jaw. This will expose the inferior longitudinal muscle.
9. Observe the styloglossus and hyoglossus merging with the fibers of the intrinsic muscles of the tongue. Follow the course of these muscle fibers to the apex of the tongue.
10. Locate the boundary between the inferior longitudinal muscle and the genioglossus near where the tongue rests within the jaw.
11. Identify and separate out with a probe the different fibers of the intrinsic muscles of the tongue.

8. The Larynx

The purpose of this dissection is to open up the larynx and observe the vocal folds. Adjustments of the larynx have multiple and interacting functions in speech, not all of which are well understood. The major movements that are relevant for speech production are the following.

(a) Abducting/Adducting vocal folds. To abduct means to move away from the midline of the body, and thus to open or pull apart, to adduct means to bring toward the midline, and thus to close or bring together (Latin ‘ab’ from, ‘ad’ to). The vocal folds can be fully adducted, for a glottal stop, or loosely adducted so that they vibrate for voiced sounds. The main muscles involved in adduction are the interarytenoid muscles, which bring the posterior ends of the vocal folds together by moving the arytenoid cartilages together. In production of voiceless sounds the vocal folds are abducted by moving the vocal folds apart. This is principally achieved by using the posterior cricoarytenoid muscles to separate the arytenoid cartilages.

(b) Lengthening/Shortening vocal folds. The pitch of voiced sounds is largely controlled by varying the length of the vocal folds. As the folds are lengthened their mass per unit length is reduced, and consequently they vibrate faster. The folds are attached to the thyroid cartilage at the front and to the arytenoid cartilages, which ride on the cricoid cartilage, at the rear so their length is largely controlled by moving the thyroid and cricoid cartilages relative to each other. EMG studies suggest that lengthening the vocal folds is mainly achieved by using the cricothyroid muscles. It is also observed that the whole laryngeal structure tends to rise as pitch rises, therefore external laryngeal muscles must also be strongly involved in pitch raising. It is unclear how much active shortening of the folds is possible; most likely pitch lowering is mainly achieved by relaxation of muscles used to reach a higher pitch.

(c) Raising/Lowering of larynx. Apart from the role that larynx raising plays in pitch control, the larynx is also raised or lowered to provide the initiation for glottalic sounds, such as ejectives (raising) and imposives (lowering), and to adjust the volume of the pharyngeal cavity. In this way the pharyngeal cavity is often enlarged for voiced obstruents and for advanced tongue root [+ATR] vowels and contracted for retracted tongue root [- ATR] vowels.

(d) Tensing/Relaxing vocal folds. Since the vocal folds consist in part of muscle (the vocalis portion of the thyroarytenoid muscle), they can also be inherently tensed and relaxed. It is probable that the degree of contraction of the vocalis fibers contributes to different modes of phonation.

Further comments on some of these functions will be made in the course of viewing and dissecting the intrinsic laryngeal structures described in this section.

Dissection

In this dissection you will first identify the previously exposed extrinsic muscles of the larynx. Then you will expose and explore the intrinsic muscles of the larynx.

The extrinsic muscles of the larynx

Most of the extrinsic muscles have been revealed in earlier dissections, particularly the dissection of the strap muscles of the neck and the dissection of the tongue.

1. Review the location of the seven hyoid and laryngeal elevators

   Anterior and posterior bellies of the digastric (the posterior belly originates on the mastoid process of the temporal bone and runs through a sling at the hyoid bone; the anterior belly originates on the inside of the mandible and runs through the same sling at the hyoid bone).

   Stylohyoid muscles (originates on the styloid process of the temporal bone and inserts into the hyoid bone).

   Mylohyoid muscles (originates on the underside of the mandible and inserts into the hyoid bone).

   Geniohyoid muscles (originates on the inside of the chin and inserts into the hyoid bone).

   Genioglossus muscles (originates on the inner surface of the mandible, superior to the geniohyoid muscle and inserts into the tongue and the anterior surface of the hyoid bone).

   Hyoglossus muscles (arises from the greater horns of the hyoid bone and inserts into the sides of the tongue).

   Thyropharyngeus muscles (arises from the back of the pharynx muscles and inserts into the horns of the thyroid cartilage).

2. Review the location of the four hyoid and laryngeal depressors

   The sternohyoid muscles (originate at the top of the sternum and inserts into hyoid bone).

   The superior and inferior bellies of the omohyoid muscles (the inferior bellies originate at the shoulder blades, the superior bellies originate at the side of the hyoid bone and they are joined by a tendon).

   The sternothyroid muscles (originate at the sternum and the first cartilaginous rib and inserts into the thyroid cartilage).

   The thyrohyoid muscles (originate at the thyroid cartilage and insert into the greater horn of the hyoid bone). This muscle both raises the larynx and depresses the hyoid bone.

The intrinsic muscles of the larynx

1. Locate the thyroid cartilage (Figure 8.1). On the lateral border observe the cricothyroid muscle which arises from the arch of the cricoid cartilage and has two parts: one part inserts into the lower border of the thyroid cartilage, and the other is inserted diagonally into the anterior border of the inferior horn of the thyroid cartilage.

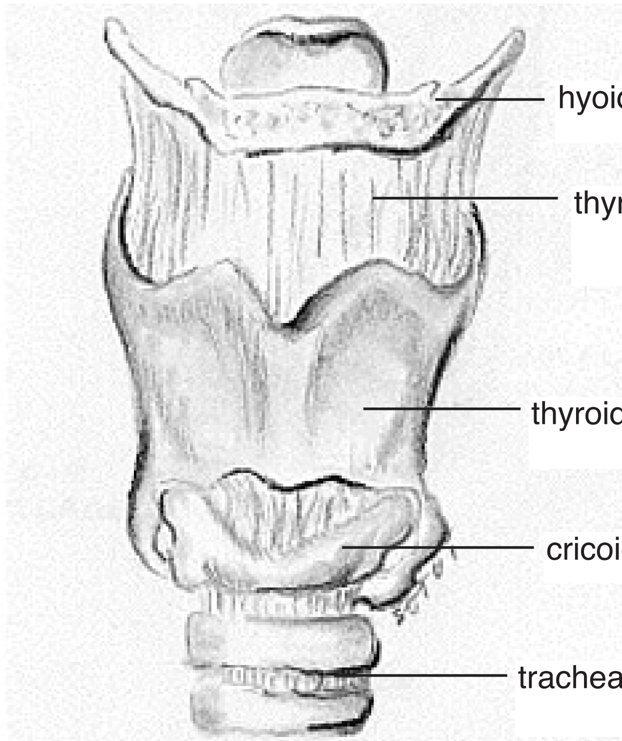


Figure 8.1. The laryngeal region, anterior (front) view. The cricothyroid muscle has been removed.

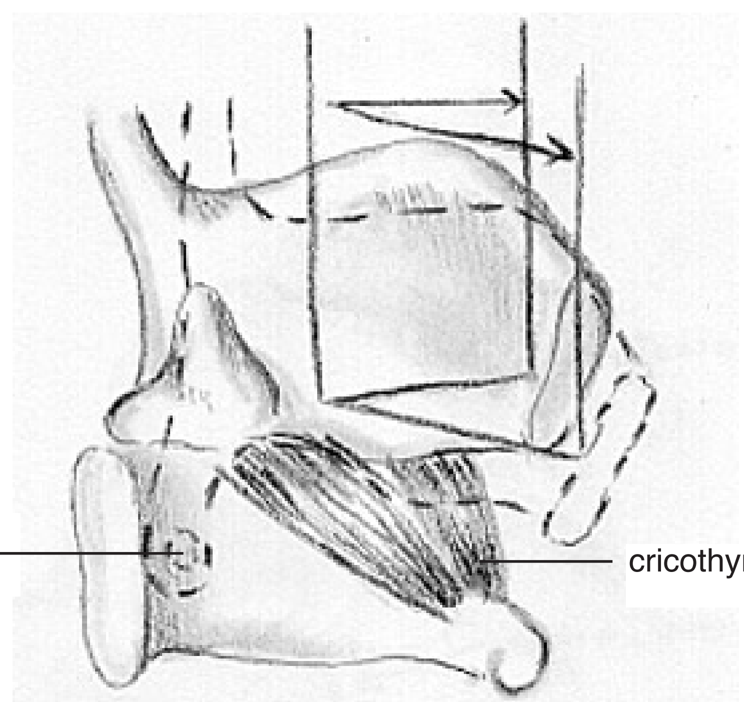


Figure 8.2. Action of the cricothyroid muscles (after Netter).

2. Locate the cricothyroid joint. The cricothyroid joint allows for rotation of the thyroid

cartilage around a transverse (horizontal) axis which runs between the inferior horns of the thyroid cartilage. In this manner, the front of the thyroid cartilage draws either towards or away from the front of the cricoid cartilage. Contraction of the cricothyroid muscle rotates the thyroid cartilage forward and relaxation allows other muscles to rotate the thyroid cartilage backward, as shown in figure 8.2. Tilt the thyroid and cricoid cartilages back and forth and observe the effects on the vocal folds,

3. Locate the vocal folds. The vocal folds run from the front of the thyroid cartilage to slightly above the back of the cricoid cartilage. Therefore, forward rotation of the thyroid cartilage lengthens and tenses the vocal folds while backward rotation shortens and relaxes them.

4. Remove the mucous membrane which surrounds the posterior aspect of the larynx by using a pair of fine forceps and scissors. Lift the membrane away from the underlying structure with the forceps and cut the fascia which anchors the mucous membrane to the muscles below, which are shown in figure 8.3.

5. Place your finger into the larynx and palpate for the arytenoid cartilages, which are sitting on top of the cricoid cartilage. The arytenoid cartilages are triangular in shape and there are three processes (angles). The muscular process is connected to the cricoid cartilage by the posterior cricoarytenoid muscle. The vocal process is connected to the thyroid cartilage by the vocal folds and thyroarytenoid muscle. The third angle is called the apex. Each apex has a tiny corniculate cartilage sitting on top of it.

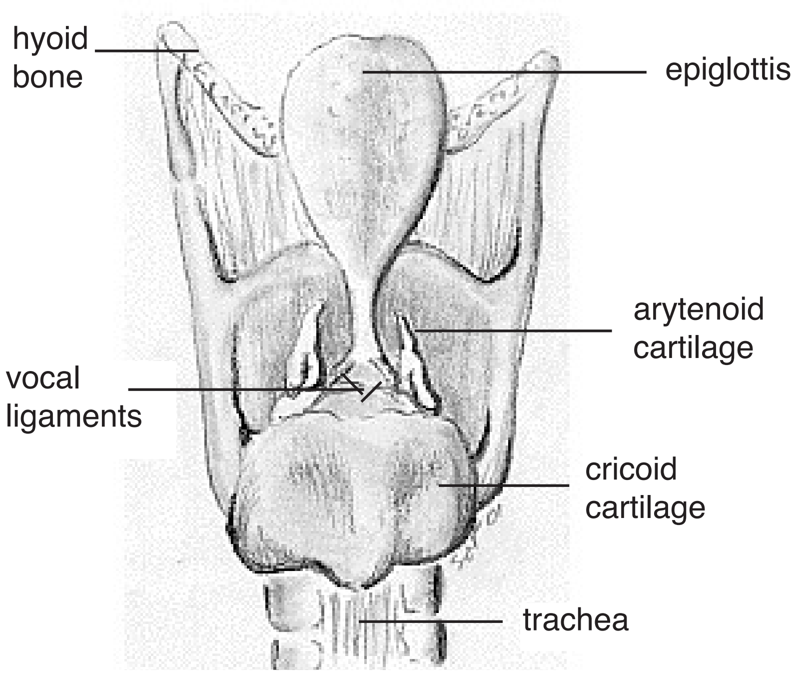


Figure 8.3. The larynx viewed from the back, after the removal of the mucous membrane that surrounds the posterior aspect of the larynx.

6. Locate the posterior cricoarytenoid muscles, fan shaped muscles which arise from both

sides of the midline of the posterior aspect of the cricoid cartilage. This muscles insert into the muscular processes of the arytenoid cartilages.

The cricoarytenoid joint is saddle shaped. Imagine a saddle (each arytenoid cartilage) fitting over a cylinder. This type of joint affords two kinds of motion: the saddle can slide along the cylinder's axis or it can slide around the cylinder - rotating about the cylinder's axis. The posterior and lateral cricoarytenoid ligaments constrain the sliding motion which the arytenoid cartilage can make.

Contraction of the posterior cricoarytenoid muscle exerts a posteroinferior (back and downward) force on the muscular process of the arytenoid cartilage. This rotates the arytenoid posteriorly over the top of the cricoarytenoid joint. The two arytenoid cartilages thus rotate outward and away from one another. This abducts (pulls apart) the vocal folds.

7. Locate the oblique arytenoid muscles superior to the posterior cricoarytenoid muscles. Each one of these muscles runs from the medial half of the muscular process of the arytenoid cartilage diagonally across to the apex of the opposing arytenoid cartilage on the other side of the larynx, forming an “X”.

8. Locate the transverse arytenoid muscle deep to the oblique arytenoid muscles. The transverse arytenoid muscle is an unpaired muscle.

   Contraction of both the oblique arytenoid muscles and the transverse arytenoid muscle—often referred to jointly as the interarytenoids—acts to adduct (pull together) the vocal folds. The oblique arytenoid muscles draw the apex of each arytenoid cartilage toward the muscular process of the other arytenoid cartilage. Because of the character of the cricoarytenoid joint, the arytenoid cartilages must rotate forward to allow such an approximation. This rotation, in turn, adducts the vocal folds. Contraction of the transverse arytenoid muscle will have a similar effect.

   To better visualize this motion, cross your hands at the wrists and make “mirror Ls” with your thumb and forefinger. Your thumbs represent the muscular processes of the arytenoid cartilages and your forefingers represent the vocal processes of the arytenoid cartilages with invisible vocal fold extending from them. To adduct the “vocal folds” rotate your forefingers inwards and downwards in imitation of the action of the arytenoid cartilages.

9. Split the thyroid cartilage down the midline using a sharp scalpel.

10. Dislocate the joint formed by the inferior cornu of the thyroid cartilage with the cricoid cartilage by prying the thyroid cartilage away from the cricoid cartilage with your finger. You should now be able to pull forward half of the thyroid cartilage and examine the lateral external aspect of the larynx.

11. Locate the lateral cricoarytenoid muscles which originate from the superior aspect of the back of the cricoid cartilage and run posterosuperiorly (from the back and upwards) to attach to the muscular processes of the arytenoid cartilages. Contraction of these muscles pulls the muscular processes of the arytenoid cartilages forward and medially. This action causes adduction and/or lengthening of the vocal folds.

12. Open the laryngeal cavity along the split in the thyroid cartilage to view the inside of the larynx.

13. Locate the laryngeal vestibules inside the larynx. These are longitudinal furrows between two folds in the laryngeal wall. The superior fold is the vestibular fold, also known as the false vocal fold. The inferior fold is the true vocal fold.

14. Locate the true vocal folds. They may be yellowish along the edge where the muscle gives way to ligament. The thyroarytenoid muscles lie beneath the vocal folds and attach the posterior aspect of the thyroid cartilage to the vocal process of the arytenoid cartilages. The thyroarytenoid muscle has an antagonistic effect to that of the cricothyroid muscle. The thyroarytenoid muscle tilts the thyroid cartilage backwards, thus shortening the vocal folds.

15. Remove the mucosa from a true vocal fold, exposing the vocalis muscle beneath. The vocalis muscle is a subset of the muscle fibers of the thyroarytenoid muscle which lie directly beneath the true vocal folds. It is not practical to try to make this distinction between thyroarytenoid and vocalis muscle fibers during the dissection.

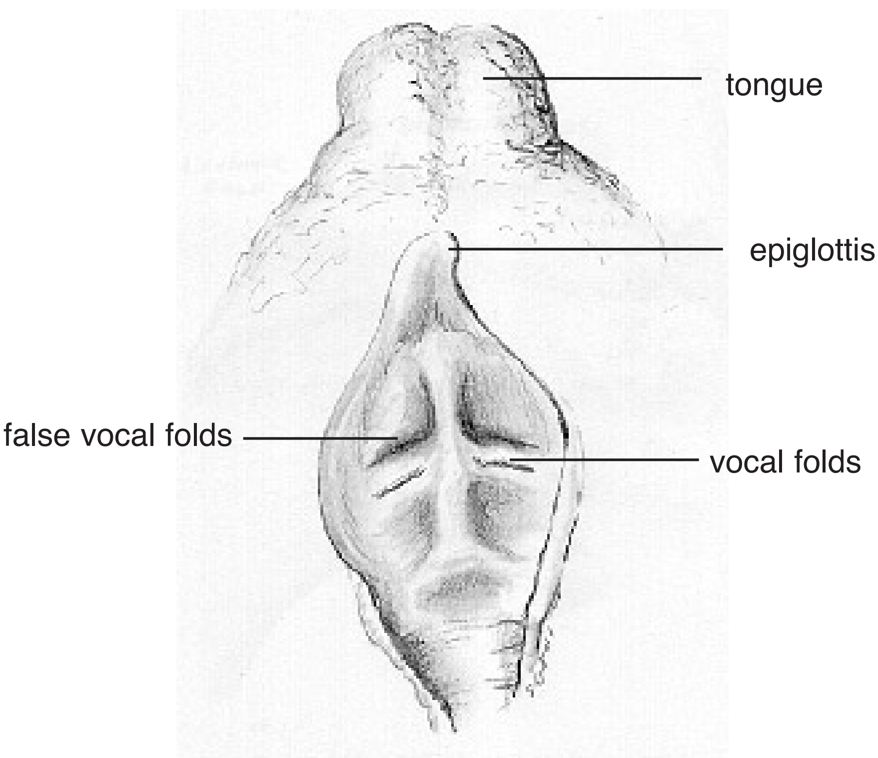


Figure 8.4. The larynx opened from behind.

16. Cut the interarytenoid muscles and the posterior cricoarytenoid muscles away from the muscular process of the arytenoid cartilage on one side of the cricoid cartilage. Locate the muscular process of the arytenoid cartilages.

17. Rotate the arytenoid cartilages forward and backward on the cricoid cartilage, observing

how this movement affects the vocal folds. (Figure 8.5.)

18. Remove an arytenoid cartilage from the larynx by detaching any of its remaining muscular attachments. Clean off all remaining bits of muscle. Identify the vocal and muscular processes. On the cricoid cartilage, locate the joint that the arytenoid cartilage makes with it. Inspect the shape of the facets on the cricoid and arytenoid cartilages, verifying that the joints allow the rotational movements described above.

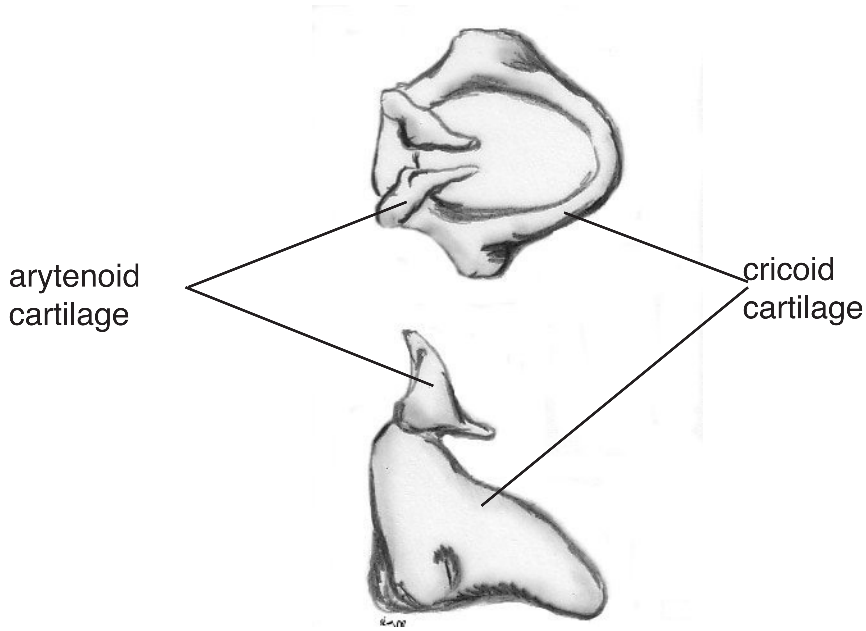


Figure 8.5. Articulation of the cricoid and arytenoid cartilages.
Superior view (top) and lateral view (side); anterior to the right of figure.

19. Detach any remaining muscles from the hyoid bone so that the thyrohyoid membrane can be observed (see figure 8.1). When the hyoid bone is raised, as the result of raising the tongue in the production of high vowels, this connection may result in an upward pull on the anterior portion of the thyroid cartilage. This will in turn lengthen the vocal folds and raise the pitch of the vowel.

9. The Velum

The palate is generally defined as the roof of the oral cavity and separates the nasal and oral cavities from one another. It is divided into a region with underlying bone called the hard palate and a region made up of connective tissue and muscle called or soft palate, or velum. (The terms 'soft palate' and 'velum' as used by linguists and phoneticians are largely interchangeable. We will continue to use the term 'soft palate,' since the term "velum" is often used to refer to other membranous tissues in the body.) The hard palate comprises about two thirds of the palate; the soft palate makes up the posterior third of the palate. The hard palate is fixed and immovable because it is made of bone; the soft palate is fleshy and moveable because it is made of muscle. The opening between the oropharynx and the nasopharynx is regulated by movement of the soft palate. This action controls the degree of nasality speech sounds. Additionally, the soft palate raises so the food will pass down into the esophagus and not up into the nasal cavity.

Elevation of the soft palate is achieved by the contraction of the tensor palatini and levator palatini muscles. The tensor palatini originates at the scaphoid fossa between the medial and lateral pterygoid plates (on the inside of the skull at the same level as the bottom of the nose) and passes around the hook of the hamulus (part of the medial pterygoid plate) to insert into the soft palate. The tensor palatini tenses and flattens the soft palate by pulling laterally. The levator palatini originates at the temporal bone and the middle of the eustachian tube and inserts into the soft palate lateral to the uvula. Contraction of the levator palatini elevates and retracts the soft palate.

Depression of the soft palate is achieved through the contraction of the palatoglossus and palatopharyngeus muscles. These muscles form the body of the faucal pillars from which the uvula hangs and were observed during the dissection of the tongue.

Dissection

Before beginning the dissection, obtain a skull and observe the pterygoid plates. Note that the "wings" of the pterygoid plates may be broken off as they are delicate structures.

1. Locate the uvula and the pillar of fauces from which it hanges. Underneath the mucosa lie the palatoglossus and palatopharyngeus muscles. Remove the mucosa to expose the fibers of these muscles.

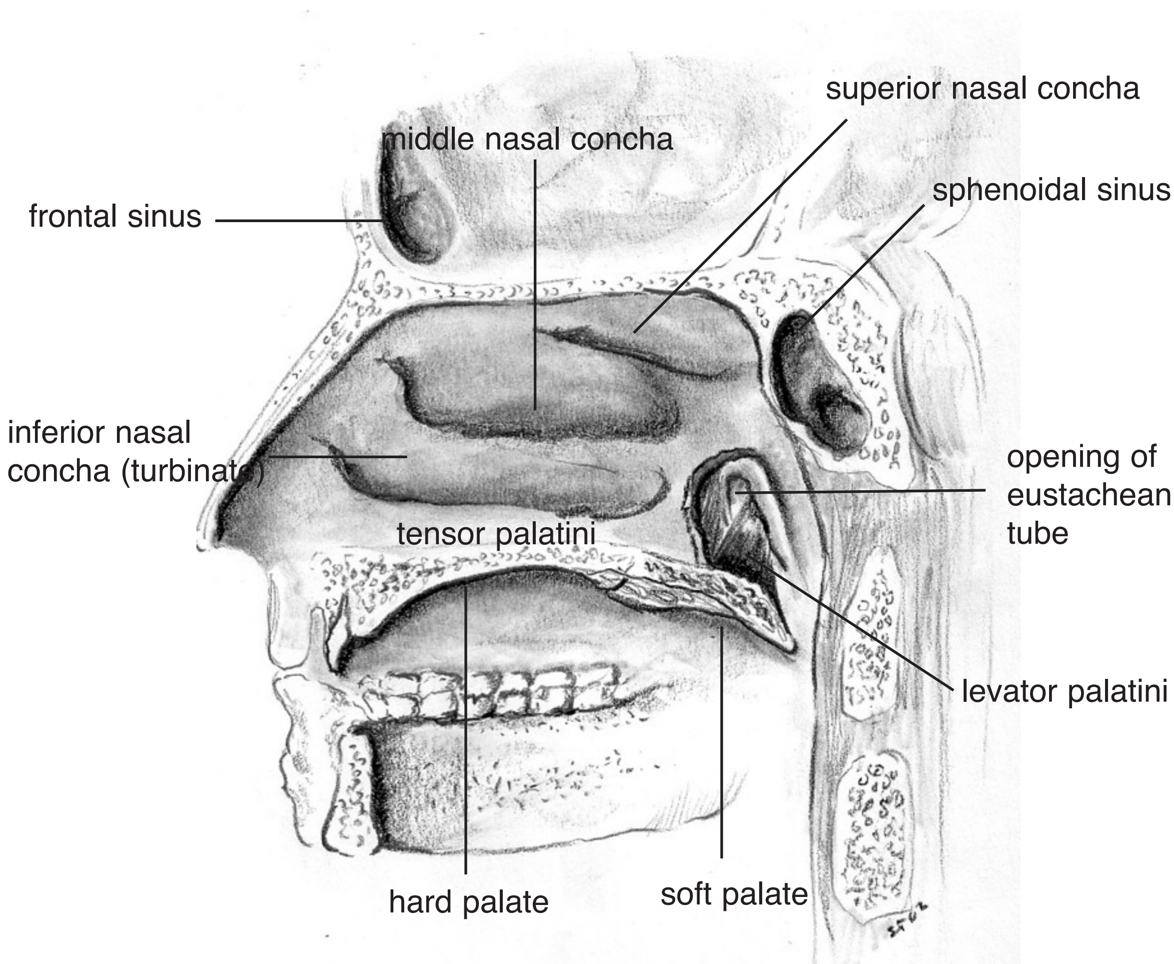
2. Bisect the skull sagitally using a bone saw and chisel as necessary.

3. Examine the nasal cavity and nasopharynx. Note how the nasal cavity is perpindicular to the nasal septum (this is why fiberscopes inserted in the nose must be pushed straight back and not up).

4. Remove the nasal septum on the side of the head where it may still be intact.

   The lateral wall of the nasal cavity has three bony conchae attached to it, the superior, middle, and inferior. These conchae, or turbinates, are thin bones covered by mucosa which increase the surface area of the nasal cavity.

5. Locate the opening of the tympanopharyngeal (eustachian) tube. This passageway



serves Figure 9.1. Mid-sagittal section of the head.

to interconnect the middle ear cavity to the nasopharynx. (This is why yawning relieves pressure in your ears.)

6. Remove with a scalpel the mucosa around the opening of the eustachian tube.

7. Find the levator palatini muscle beneath the mucosa. This muscle originates from the petrous bone (which is part of the medial and lateral pterygoid plates) and part of the eustachian tube and inserts into the soft palate.

8. Locate the medial pterygoid plate behind the nasal passage. Remove the mucosa covering the medial pterygoid plate.

9. Locate the tensor palatini muscle directly lateral to the medial pterygoid plate.

10. Fracture the medial pterygoid plate with a small chisel, (try not to break the hamulus of the medial pterygoid plate) and remove the pieces. The tendinous fibers of the tensor palatini should now be seen.

11. Isolate the muscle fibers of the tensor palatini in as best you can. Note that the fibers of the tensor palatini which insert into the soft palate split into two separate groups of fibers.

Appendix A: Glossary of Anatomical Terms

Not all the terms in this list appear in the dissector. However, they may be encountered in supplementary reading.

abduction	drawing away from midline
adduction	drawing toward the midline
adherent	sticking or clinging (< adhere)
alveolus	pouch in lung air sac
anterior	situated before or in front of (also ventral)
aorta	the large artery carrying oxygenated blood away from the heart
aponeurosis	a dense shiny fascia with all the fibers running in the same direc tion, forming a tendon
apposition	a fitting together
artery	vessel carrying blood away from the heart
articulation	connection between bones
autonomic nervous system	innervation of smooth muscle, heart muscle and glands
belly	central part of a muscle
body (of bone)	broadest or longest mass of bone
brachium	arm or branch
brainstem	base of the brain joining the spinal cord, includes the medulla oblongata, pons, and the midbrain
bronchus	one of two branches of the trachea entering the lungs
buccal	belonging to the cheek
cartilage	substance from which some bone ossifies; gristle
caudal below;	farther from the head (also inferior)
central nervous system	the brain and spinal cord (abbreviated CNS)
cervical (vertebrae)	pertaining to the neck
clavicle	the collarbone; a long bone articulating the sternum medially and the scapula laterally
cornu	a small, horn-shaped projection of a bone (pl. cornua, adj. corniculate)
coronal	vertical; at right angles to sagittal (also frontal)
cortex	the outer portion of an organ, particularly the brain; gray matter
costal	pertaining to the ribs
cranial	upper; nearer to the head (also superior, rostral)
cranium	the skull; the portion of the skull containing the brain
deep	farther from the surface
depressor	that which lowers
dilator	that which regulates the opening of an aperture; a muscle that expands or enlarges an opening
distal	farther from a point of attachment
dorsal	toward the rear, back (also posterior); used esp. for the brain
eminence	a projection or prominence (of bone)
esophagus	muscular tube through which food is carried from the pharynx to

	the stomach
extension	straightening
fascia	a sheet of fibrous connective tissue that covers muscle
flexion	bending or angulation
foramen	hole, e.g. the foramen magnum is the hole in the skull through which the spinal cord connects to the brain stem (pl. foramina)
fossa	shallow depression (pl. fossae)
frontal	vertical; at right angles to sagittal (also coronal)
ganglion	group of nerve cells outside the CNS (pl. ganglia)
genioid (process)	pertaining to the chin (adj. genial; < Gk. gena 'chin'; see also mental)
gland	an organ or group of cells which secrete fluid
gyrus	a "hill" on the surface of the brain (pl. gyri)
head (of bone)	enlarged around end of a long bone; knob
in situ	in position
inferior	below; farther from the head (also caudal)\
innervate	to provide nerves (to muscles)
innervation	the distribution of nerves to an area
insertion	the area of attachment of a muscle to bone
interdigitate	to join finger-like branches
jugular notch	a "valley" or depression at the top of the sternum where the clavicles attach
jugular	pertaining to the neck
lamina	plate or layer (of bone)
lateral	farther from the midline
levator	that which raises
ligament	fibrous tissue binding bones together or holding tendons and muscles in place
lingual	belonging to the tongue
lumbar (vertebrae)	pertaining to the base of the torso; any of five vertebrae near the bottom of the spinal column
malar	belonging to the cheek
mandible	the jaw bone
manubrium	platelike bone forming the superior part of the sternum
margin	border
maxilla the	bone forming the upper jaw
meatus	an opening to the body
medial	nearer to midline
(osseus) membrane	a thin layer of tissue; the osseous membrane covers bone; the thyrohyoid membrane connects the thyroid cartilage and hyoid bone
midline	line dividing the body into left and right sides
mucosa	mucous membrane
neck (of bone)	constriction of bone near head

nerve	group of fibers outside the CNS
nucleus	group of nerve cell bodies inside the CNS
oblique	slanting
occiput	the back part of the head or skull
origin	fixed part of a muscle
palpate	to examine by touch
parietal	on the side or top; the parietal pleura is the pleural membrane facing the outside (cf. visceral)
pericardium	the membrane (actually an extension of the visceral pleura) covering and containing the heart (adj. pericardial)
pleura	the membrane(s) covering the lungs and inside of the thorax (cf. parietal, visceral; pl. pleurae)
plexus	a collection of nerve fibers
pons	structure of the brainstem connecting the medulla oblongata, midbrain and cerebrum
process (of bone)	projection
proximal	nearer to a point of attachment
pterygoid	wing-shaped; pertaining to the pterygoid bone, inferior to the sphenoid bone of the skull
pulmonary trunk	the region of the bronchus as it enters the lung
ramus	plate-like branch of bone; branch of a vessel or nerve
raphe	union of two parts (in a line)
reflect	pull or bend back
rostral	upper; nearer to the head (also cranial, superior)
sagittal	vertical plane or section dividing body into right and left
scapula	the shoulder blade
septum	a membrane or other structure separating two related structures (pl. septa)
serous	watery
sphincter	a circular band of muscle fibers that constrict an opening
sternum	the breastbone
subcutaneous	deep to the skin
sulcus	a "valley" on the surface of the brain (pl. sulci)
superficial	nearer to the surface
superior	upper; nearer to the head (also rostral, cranial)
tendon	fibrous tissue securing a muscle to its attachment (adj. tendinous)
tensor	that which draws tight
thoracic cavity	the inside of the rib cage; region of the heart and lungs
trachea	tube connecting the pharynx with the lungs
transverse	at right angles to long axis (also horizontal)
tubercle	small bump (can be felt with finger)
umbilicus	the navel
vascular	pertaining to the circulatory system, particularly arteries and veins
vein	vessel returning blood to the heart

viscera	soft organs of the body
visceral	pertaining to the viscera; the visceral pleura is the layer of the pleura that faces the lungs (cf. parietal)

Notes on terminology

1. Muscles are often identified by where they originate and where they terminate. For example, the sternohyoid muscle originates at the sternum and terminates at the hyoid bone.

2. The nerve roots that exit from the spinal cord are often abbreviated by the section of the spinal cord from which they emerge and their number (i.e. how far down the cord they are at that particular level). For example, C1 is the first (most superior) nerve root which exits the cord at the cervical level (the most superior).

Appendix B: Muscles of the Speech Production Mechanism

I. MUSCLES OF RESPIRATION

A. MUSCLES OF INHALATION (muscles that enlarge the thoracic cavity)

1. Diaphragm

Attachments: The diaphragm originates in a number of places: the lower tip of the sternum; the first 3 or 4 lumbar vertebrae and the lower borders and inner surfaces of the cartilages of ribs 7 - 12. All fibers insert into a central tendon (aponeurosis of the diaphragm).

Function: Contraction of the diaphragm draws the central tendon down and forward, which enlarges the thoracic cavity vertically. It can also elevate to some extent the lower ribs. The diaphragm separates the thoracic and the abdominal cavities.

2. External Intercostals

Attachments: The external intercostals run from the lip on the lower border of each rib inferiorly and medially to the upper border of the rib immediately below.

Function: These muscles may have several functions. They serve to strengthen the thoracic wall so that it doesn't bulge between the ribs. They provide a checking action to counteract relaxation pressure. Because of the direction of attachment of their fibers, the external intercostals can raise the thoracic cage for inhalation.

3. Pectoralis Major

Attachments: This muscle attaches on the anterior surface of the medial half of the clavicle, the sternum and costal cartilages 1-6 or 7. All fibers come together and insert at the greater tubercle of the humerus.

Function: Pectoralis major is primarily an abductor of the arm. It can, however, serve as a supplemental (or compensatory) muscle of inhalation, raising the rib cage and sternum. (In other words, breathing by raising and lowering the arms!) It is mentioned here chiefly because it is encountered in the dissection.

4. Pectoralis Minor

Attachments: Deep to pectoralis major, this muscle attaches to the coracoid process of the scapula and the anterior ends of ribs 2 - 5.

Function: This muscle is also not primarily for respiration. Its main function is to lower the shoulder. If the pectoral girdle is fixed, it may, however, cooperate with pectoralis major in raising the upper ribs. It has been found to be active in forced inhalation.

B. MUSCLES OF EXHALATION (muscles that decrease the volume of the thoracic cavity)

1. Internal Intercostals

Attachments: The internal intercostals run from the anterior limits of the intercostal spaces to the angle of the ribs posteriorly. In front, they run inferiorly and laterally, and in back inferiorly and medially. Each muscle runs from the subcostal groove of one rib to the top of the rib immediately below it.

Function: The internal intercostals assist the external intercostals in strengthening the intercostal spaces. The internals are also the chief muscle in forced exhalation, for example during phonation. The internal intercostals - aided by the abdominal muscles - pull down the rib cage because of the direction of their fibers (opposite to the external intercostals). Note: as defined here, nerve fibers run within the internal intercostal muscles. Some researchers thus distinguish the 'internal' intercostal fibers, which are superficial to this nerve, from the 'innermost' intercostals, which are deep.

2. Internal Obliques

Attachments: The internal obliques originate in the lateral half of the inguinal ligament and the anterior half of the iliac crest. The fibers course almost vertically up to the lower borders of the cartilages of the last 3 or 4 ribs and the abdominal aponeurosis.

Function: The internal obliques assist other muscles in compressing the abdomen and thus raising the diaphragm and decreasing the vertical dimension of the thoracic cavity. They may also pull down on the lower three ribs.

3. External Obliques

Attachments: These muscles originate in the exterior surfaces and lower borders of ribs five to twelve. The fibers run in two directions: a) inferiorly and medially to the anterior half of iliac crest and near the midline of the abdominal aponeurosis and b) to the external layer of the abdominal aponeurosis.

Function: The external obliques compress the abdomen and draw the lower ribs downward. They may be used in forced exhalation.

4. Rectus Abdominis

Attachments: Rectus abdominis attaches at the crest of the pubis. The fibers run superiorly to the cartilage of the fifth, sixth and seventh ribs and the xiphoid process.

Function: This muscle is also used in forced exhalation. It can pull the ribs down and thus decrease the thoracic cavity and also push in on the abdomen forcing the diaphragm upwards thereby forcing air out of the lungs.

5. Transversus Thoracic

Attachments: Transversus thoracic originates on the inner surface of the lower part of the sternum. The fibers run superiorly and laterally to the lower borders and inner surfaces of ribs two to six.

Function: These muscles may help to depress ribs for exhalation and may also tighten the intercostal spaces to help maintain the rigidity of the thoracic wall.

II. MUSCLES OF LIP MOVEMENT

A. MUSCLES THAT CLOSE THE LIPS

1. Orbicularis Oris

Attachments: Orbicularis Oris is the sphincter muscle of the mouth, many of the other facial muscles blend in with it. Its fibers run in several directions. The intrinsic fibers extend from the incisive slips under the nose to the mental slips at the midline under the lower lip. The extrinsic fibers arise from the buccinator through the modiolus. The uppermost and lowermost fibers go directly across the upper and lower lips to the other side. The middle fibers cross each other, the upper ones going below the lower lip and the lower ones going above upper lip.

Function: On contraction, this muscle adducts the lips by drawing the lower lip up and the upper lip down, probably in conjunction with some of the other facial muscles. It may also pull the lips against the teeth. This muscle can also round the lips by its sphincter action.

B. MUSCLES THAT RAISE THE UPPER LIP

1. Levator Labii Superioris

Attachments: This muscle originates on the inferior orbital margin and parts of the zygomatic bone. The fibers course inferiorly and insert in the upper lip.

Function: As its name indicates, levator labii superioris raises the upper lip. It may be used to raise the upper lip in the production of labiodental fricatives.

2. Levator Labii Superioris Alaeque Nasi

Attachments: This muscle originates on the frontal process of the maxilla (the bone forming the upper jaw). The fibers run inferiorly and laterally along the sides of the nose and divide into two slips. One slip inserts in the alar cartilage (around nostril) and the other continues down to the upper lip.

Function: The muscle elevates the alar cartilages (dilates nostrils) and also elevates the middle part of the upper lip.

3. Zygomaticus Minor

Attachments: Zygomaticus minor originates on the facial surface of zygomatic bone. Running inferiorly and medially, the fibers insert into the modiolus and orbicularis oris, just lateral to the midline.

Function: Raises upper lip for [f] along with the muscles that raise the angles of the mouth.

C. MUSCLES THAT LOWER THE BOTTOM LIP

1. Depressor Labii Inferioris

Attachments: Depressor labii attaches on the oblique line of mandible near mental foramen. Fibers run superiorly and medially to orbicularis oris and the skin of the lower lip.

Function: Draws lower lip downward and laterally, useful in the release of bilabial consonants.

D. MUSCLE FOR ROUNDING THE LIPS

1. Orbicularis Oris (see under muscles that close the lips)

E. MUSCLES THAT PROTRUDE THE LIPS

1. Mentalis

Attachments: Mentalis originates on the mandible near mental tuberosity (point of the chin). Fibers course superiorly, some reaching orbicularis oris, others inserting at different places along the way.

Function: On contraction, mentalis draws the skin on the chin upwards, at the same time everting and protruding the lower lip. In conjunction with orbicularis oris it helps round and protrude the lips for the high rounded vowels [u] and [y]. It also may help to close lips.

2. Orbicularis Oris--deep fibers (see under muscles that close the lips)

F. MUSCLES THAT RETRACT THE ANGLES OF THE MOUTH

1. Buccinator

Attachments: Buccinator attaches to the pterygomandibular raphe and lateral surfaces of the mandible and the maxilla (the upper jaw) opposite the molar teeth. The fibers course medially and insert in the modiolus, with some continuing on into the upper and lower lips, forming the more superficial fibers of orbicularis oris.

Function: The buccinator draws the lips back against the teeth and pulls the angles of the mouth laterally as an antagonist to the muscles of protrusion and rounding. This action is probably utilized in the production of labiodental and bilabial fricatives. If the lips are actively spread in pronunciation of vowels such as [i] and [e] (which seldom happens), this muscle may be used.

2. Risorius

Attachments: The risorius is sometimes regarded as an extension of the platysma. The fibers have their origin at the fascia of the masseter near the ramus of the mandible. The fibers run horizontally, parallel and superficial to the buccinator, inserting in the modiolus, some continuing on to the upper and lower lips.

Function: The risorius draws the mouth angles laterally to help spread the lips in the production of [i] and [e] (although note the comment in the discussion of buccinator.). It may also aid the buccinator and zygomaticus major in pulling back the angles of the mouth during labiodental and bilabial fricatives.

3. Zygomaticus Major

Attachments: Zygomaticus major attaches on the outer edge of zygomatic bone, just lateral to zygomaticus minor. In some cases it inserts into the more superficial connective tissue that extends to cover the temporalis muscle. The fibers course inferiorly and medially to insert into the modiolus and orbicularis oris of the upper lip.

Function: On contraction, this muscle draws the angle of the mouth upward and laterally. The upward movement probably works with levator anguli oris to achieve the raised upper lip in labiodental fricatives. The lateral movement may be used in the production of [s].

G. MUSCLES THAT RAISE THE CORNERS OF THE MOUTH

1. Levator Anguli Oris

Attachments: Levator anguli oris runs from the canine fossa on the maxilla coursing inferiorly and slightly laterally; most fibers insert in the modiolus with a few continuing on to insert in the lower lip.

Function: This muscle draws the corner of the mouth upwards and, because of the fibers that insert into the lower lip, may assist in closing the mouth by drawing the lower lip up, for the closure phase in bilabial consonants.

2. Zygomaticus Major (see under muscles that retract the angles of the mouth)

H. MUSCLES THAT LOWER THE ANGLES OF THE MOUTH

1. Depressor Anguli Oris

Attachments: Depressor anguli oris attaches to the oblique line of mandible. This muscle is superficial and lateral to depressor labii inferioris. It runs vertically upwards, interdigitating with the platysma, and inserts into the modiolus. Some fibers continue up to the upper lip.

Function: This muscle depresses the angles of the lips. This action may work with depressor labii inferioris to prevent the mouth from closing entirely when spreading for vowels like [i] and [e]. Because of the fibers that insert in the upper lip, this muscle may also aid in compressing lips by drawing the upper lip down.

2. Platysma

Attachments: Platysma originates in the fascia covering superior parts of pectoralis major and deltoid muscles. Fibers course superiorly and anteriorly, some inserting into the lower border of the mandible, blending with depressor labii inferioris and depressor anguli oris, some turn more medially and met the corresponding fibers from the other side on the chin, some go up into the modiolus, and some even continue up to the zygomatic arch and orbicularis occuli.

Function: The platysma can aid depressor anguli oris and depressor labii inferioris to draw down and laterally the angles of the mouth.

III. MUSCLES OF MANDIBULAR MOVEMENT

A. MUSCLES THAT RAISE THE MANDIBLE

1. Masseter

Attachments: The masseter has its origin at the zygomatic arch. It inserts in the ramus of the mandible.

Function: This muscle closes the jaws by elevating and drawing forwards the angle of the mandible.

2. Medial Pterygoid

Attachments: The medial pterygoid originates in the pterygoid fossa and the medial surface of the lateral pterygoid plate. The fibers run inferiorly, laterally and posteriorly to the medial surface of the ramus and angle of the mandible.

Function: The medial pterygoid works with the masseter and temporalis to raise and protrude the mandible. It serves also as an antagonist to the anterior suprahyoid muscles to balance the lip position for labiodental fricatives and adjust the jaw position for [s].

3. Temporalis

Attachments: The temporalis originates from the entire temporal fossa. The fibers pass under the zygomatic arch to the anterior border of the ramus of the mandible.

Function: The function of this muscle is to raise the mandible (along with the masseter and the medial pterygoid). The posterior fibers retract the mandible slightly, assisted by the anterior suprahyoid muscles.

B. MUSCLES THAT LOWER THE MANDIBLE

1. Anterior Belly of the Digastric

Attachments: This muscle originates on the inside surface of the lower border of the mandible. The fibers course inferiorly and posteriorly to the intermediate tendon near the lesser cornu of the hyoid bone.

Function: The function of this muscle is to draw the hyoid bone up and forward. It also serves to bring the tongue forward and upward for alveolar and high front vowel articulations. In pulling up the hyoid bone, it may also pull up the larynx thereby tensing the stretching the vocal cords and raising the pitch. If the hyoid bone is fixed, the anterior belly of the digastric can serve to lower the jaw in conjunction with the geniohyoid, mylohyoid and lateral pterygoid muscles.

2. Genioglossus (see under Muscles of the tongue)

3. Geniohyoid

Attachments: Geniohyoid attaches on the anterior inner surface of the mandible at the mandibular symphasis (where the two halves of the mandible join). Fibers run posteriorly and inferiorly to the anterior surface of the body of the hyoid bone. It is close to the midline of the floor of the mouth.

Function: When the mandible is fixed, the geniohyoid (along with the lateral pterygoid, the anterior belly of the digastric and the mylohyoid) pulls the hyoid bone upward and forward. This will raise both tongue and larynx. The geniohyoid may also serve as an antagonist to the thyrohyoid, tilting the hyoid and with it the thyroid cartilage backward, for velar and uvular articulations. If the hyoid bone is fixed by other muscles, the geniohyoid can become an active jaw opener.

4. Mylohyoid

Attachments: The mylohyoid muscle originates from the mylohyoid line along the inner surface of the mandible. Coursing medially and inferiorly, the fibers join those of the opposite side at the raphe and down to the corpus of the hyoid bone.

Function: When the mandible is fixed, the mylohyoid helps to elevate the hyoid and bring it forward and with it the floor of the mouth and the tongue. With the hyoid bone fixed, the mylohyoid may depress the mandible. It helps bring the tongue forward for alveolar articulations and, along with the posterior belly of the digastric, the stylohyoid and the medial pharyngeal constrictor, helps bulge the tongue up and back for velars. It is also active in high vowels whether front or back, in that it raises the whole body of the tongue.

5. Lateral Pterygoid

Attachments: This muscle attaches to the lateral portion of the greater wing of the sphenoid bone and the lateral surface of the lateral pterygoid plate. Running horizontally and posteriorly, the fibers insert in the pterygoid fossa and the temporo-mandibular joint.

Function: The lateral pterygoid muscle protrudes the mandible, causing the condyle to slide down and forward. This protrusion is useful in the articulation of [s] and [S] and, for some people, [f]. It can also depress the mandible along with the other depressors discussed above.

IV.MUSCLES OF THE TONGUE

A. INTRINSIC MUSCLES THAT CHANGE THE SHAPE OF THE TONGUE

1. Superior Longitudinal

Attachments: This muscle originates at the median fibrous septum and mucous membrane at the root of the tongue (close to the hyoid bone). Some fibers go back to the epiglottal ligament. The fibers course anteriorly along the length of the tongue very superficially and insert in the mucous membrane at the tip of the tongue. Laterally, the fibers join with the longitudinal fibers of the styloglossus, hyoglossus and inferior longitudinal muscles.

Function: On contraction, this muscle shortens the tongue, perhaps widening it at the same time. It can also bulge the tongue upwards as it shortens it, probably with the help of the inferior longitudinal to pull the tip of the tongue downwards. Since the fibers are inserted in the tip, this muscle can probably also raise the tip of the tongue for tongue tip dental and alveolars and retract it a bit for retroflex articulations. The lateral fibers may (along with styloglossus and perhaps palatoglossus) help keep the sides of the tongue raised during grooved articulations such as [s] and [z].

2. Inferior Longitudinal

Attachments: This muscle originates at the hyoid bone and root of tongue. Fibers course anteriorly lateral to the midline on the inferior side of the tongue between the genioglossus and hyoglossus muscles and insert into the inferior part of the tongue tip, blending with the fibers of the genioglossus, hyoglossus and styloglossus.

Function: This muscle pulls down and retracts the tip of the tongue for the release of tongue tip stop consonants. It acts as an antagonist to superior longitudinal and styloglossus for delicate control of tongue configuration as in grooving for [s]. By depressing the tip and bulging the tongue upwards, it helps from the articulations of back vowels and velar consonants.

3. Transverse

Attachments: These muscle fibers originate at the median fibrous septum. The fibers course laterally to the lateral margins of the tongue, mainly inferior to the superior longitudinal and superior to the inferior longitudinal muscles. They insert into the submucous fibrous tissue in a fan-like distribution. Near the tip of the tongue, where the median fibrous septum is not evident, they interdigitate with fibers of same muscle on the other side and with fibers of the superior longitudinal and inferior longitudinal muscles. At the root of the tongue they interdigitate with the palatopharyngeus muscle.

Function: On contraction, these fibers narrow and elongate the tongue. They draw the edges of the tongue upwards, aiding in grooving the tongue. They may also aid genioglossus in pushing the tongue forwards for front articulations when the tongue is coming from a back position.

4. Vertical

Attachments: These muscle fibers attach to the mucous membrane of the dorsum of tongue. The fibers course inferiorly and vertically on either side of the median fibrous septum, inserting in the mucous membrane on the ventral side of the tongue. Some fibers interdigitate with fibers from the transverse and inferior longitudinal muscles.

Function: On contraction, the vertical fibers flatten the tongue and push the tongue out laterally to make contact with the roof of the mouth in palatal and alveolar stops. This tongue position may also be used in high front vowels. It is also used in making a seal between the upper and lower teeth during the production of [s]. The median fibers may act independently to flatten the middle of the tongue for grooved articulations.

B. EXTRINSIC MUSCLES (muscles that change the position of the tongue in the mouth as well as shape the tongue to some extent)

1. Genioglossus

Attachments: Genioglossus runs from the superior mental spina on posterior surface of the mandibular symphasis. The lower most fibers course posteriorly back to the anterior surface of the hyoid bone. Other fibers curve and fan out anteriorly and superiorly to insert into the submucous fibrous tissue near the midline from the root of the tongue to near the tip. Some fibers may interdigitate with those of the superior pharyngeal constrictor.

Function: Contraction of posterior fibers protrudes the tongue when the mandible is fixed. This is useful in the production of nearly all sounds articulated in the front of the mouth. The anterior fibers retract the tongue on contraction and also depress the tip somewhat, and are probably used in the release of alveolar stop consonants. Besides its function as a muscle of the tongue, the genioglossus can also help to elevate the hyoid bone (and thus the larynx) when the mandible is fixed.

2. Hyoglossus

Attachments: This muscle originates on the greater horn and body of hyoid bone. The posterior and medial fibers interdigitate with the styloglossus and the inferior longitudinal muscles at the lateral edges of the tongue. Some of the anterior fibers may attach to the mucous membrane at the tip of the tongue. One small bundle coming from the lesser cornu of the hyoid bone parallels the hyoglossus and inserts in the intrinsic muscles on the side of the tongue and the tip. This is sometimes considered a separate muscle: the chondroglossus (chondro = cartilage).

Function: When the hyoid is fixed, the hyoglossus can lower the tongue. The anterior fibers join with the genioglossus and inferior longitudinal muscles to retract the lower tongue tip. The posterior fibers (which insert on the lateral edges of the tongue) pull down the sides of the tongue on contraction, thus serving as antagonists to styloglossus and palatoglossus (when the soft palate is fixed) and contribute to the delicate adjustment of grooved fricatives. It may also work with styloglossus in the production of back vowels (tongue bunching with sides down) and the anterior fibers may balance the forward action of the posterior genioglossus fibers to position the tongue precisely in front vowels.

3. Palatoglossus

Attachments: This muscle attaches to the undersurface of the soft palate, interdigitating with the opposing fibers from the other side. The fibers continue inferiorly and laterally, forming the anterior pillars of the fauces and then insert at the edges of the tongue, interdigitating with the transverse, styloglossus and hyoglossus muscles.

Function: With the soft palate fixed, the palatoglossus muscle can assist styloglossus in raising the back of the tongue. In this it serves as an antagonist to the hyoglossus. It also aids the styloglossus and inferior longitudinal muscles to bulge the back of the tongue for velars. Because it inserts in the sides of the tongue and comes from a superior origin, it may also serve to groove the back of the tongue (used by some speakers in uvular trill and fricative production). Because of the connection created by this muscle, a low tongue position may draw down the velum slightly. If the tongue is fixed, it may serve as a depressor to the soft palate.

4. Styloglossus

Attachments: Styloglossus originates at the anterior and lateral surface of the styloid process and the stylomandibular ligament. The fibers fan out and course inferiorly and anteriorly, dividing into two parts. The lower part blends with the fibers from the hyoglossus muscle. The upper part courses along the lateral edges of the tongue and blends with the fibers from the inferior longitudinal muscle near the tip of the tongue.

Function: Styloglossus elevates and draws back the tongue, acting as an antagonist to genioglossus. These two muscles work together to position the tongue for most vowels. With the posterior part of genioglossus, it helps to bring the tongue up and back for velar articulations. Since the fibers insert on the sides of the tongue, contraction of styloglossus may also elevate the tongue margins to form a groove.

V. MUSCLES OF THE SOFT PALATE

A. ELEVATORS

1. Levator Palatini

Attachments: Levator palatini originates at the apex of the petrous portion of the temporal bone and the medial wall of the Eustachian tube and runs anteroinferiorly to the posterior surface of the soft palate.

Function: Levator palatini is the primary elevator of the soft palate and pulls it posteriorly for non-nasal articulations.

2. Musculus Uvulae

Attachments: Musculus uvulae runs from the posterior nasal spine of the palatine bones and the palatine aponeurosis. It courses medially and posteriorly along the length of the soft palate and inserts in the mucous membrane of the uvula.

Function: On contraction, it shortens and lifts the soft palate and the uvula. It may help to close off the nasal cavity and may play some role in positioning the uvula for a uvular trill.

B. TENSOR

1. Tensor Palatini

Attachments: Tensor palatini originates at the sphenoid bone and the lateral wall of the Eustachian tube. Fibers course inferiorly and anteriorly becoming tendonous as they wind around the hamulus and spread out along the palatine aponeurosis.

Function: Tensor Palatini spreads and tenses the soft palate, helping to close off the nasal cavity. It also pulls on the wall of the Eustachian tube and opens it up to equalize pressure.

C. DEPRESSORS

1. Palatoglossus (see under extrinsic muscles of the tongue)

2. Palatopharyngeus

Attachments: Palatopharyngeus arises from both the anterior hard palate and the midline of thesoft palate with many fibers interdigitating with those from the opposite side. Some fibers arise from the edge of the auditory tube and form the salpingopharyngeus (which we will not discuss here since it has little, if anything, to do with speech). The fibers course inferiorly and laterally, forming the posterior pillar of the fauces, inserting into the stylopharyngeus, the lateral wall of the pharynx and the posterior border and greater cornu of the thyroid cartilage.

Function: When the thyroid cartilage and pharyngeal wall are fixed, contraction of this muscle will lower the soft palate. When the soft palate is fixed, the thyroid cartilage can presumably be raised (mostly for swallowing).

3. Passavant's Muscle

Attachments: This muscle is a part of the superior pharyngeal constrictor. It originates at the median pterygoid plate. The fibers course posteriorly along the wall of the nasopharynx and insert into the superior pharyngeal raphe.

Function: This pad of muscle is not recognized by all authorities. It forms a ridge (Passavant's Ridge) against which the levator palatini pulls the soft palate and helps form a better seal.

VI. MUSCLES OF THE PHARYNX

A. PHARYNGEAL CONSTRICTORS

1. Superior Pharyngeal Constrictor

Attachments: This muscle has several different origins and a comparable number of names: a) Originating at the lower one-third of the medial pterygoid palate and the hamulus is the pterygopharyngeus; b) Originating at the pterygomandibular raphe is the buccopharyngeus; c) From the posterior part of the mylohyoid line and adjacent alveolar process of the mandible is the mylopharyngeus and d) a few fibers from the side of the tongue are sometimes called the glossopharyngeus. All fibers insert into the midline pharyngeal raphe.

Function: These muscles narrow the upper wall of the pharynx.

2. Medial Pharyngeal Constrictor

Attachments: This muscle can be said to consist of two minor muscles: (a) the ceratopharyngeus, which originates on the superior border of the greater horn of the hyoid bone and the stylohyoid ligament; b) the chondropharyngeus (mentioned before as part of the hyoglossus) is considered by some to be part of the medial pharyngeal constrictor. The fibers run superiorly and medially to the medial pharyngeal raphe. The superior fibers overlap those of the superior constrictor.

Function: These fibers contract the pharynx during swallowing. Since it attaches on the hyoid bone, it has a minor function as a larynx elevator along with the posterior belly of the digastric and the stylohyoid.

3. Inferior Pharyngeal Constrictor

Attachments: The part of the inferior pharyngeal constrictor that arises from the thyroid lamina and the superior cornu of the thyroid cartilage and inserts into the pharyngeal raphe may be called the thyropharyngeus. Fibers arising from the cricoid cartilage and the inferior cornu of the thyroid cartilage are called the cricopharyngeus. The most inferior fibers go obliquely downward to blend with the muscle fibers of the esophagus and form a sphincter.

Function: Cricopharyngeus becomes a pseudo-glottis in laryngectomized patients; it sets the aperture of the esophagus for esophageal speech. From a fixed larynx, the inferior constrictor can constrict the lower part of the pharynx for swallowing.

VII. EXTRINSIC MUSCLES OF THE LARYNX

A. ELEVATORS

1. Anterior Belly of the Digastric (see under muscles that lower the mandible)

2. Posterior Belly of the Digastric

Attachments: This portion of the digastric muscle attaches to the mastoid process of the temporal bone. Fibers run inferiorly and anteriorly to meet the anterior belly at an intermediate tendon.

Function: The posterior belly of the digastric draws the hyoid bone superiorly and posteriorly and with it the larynx. It may also help bring the tongue into position for velar articulations.

3. Genioglossus (see under extrinsic muscles of the tongue)

4. Geniohyoid (see under muscles that lower the mandible)

5. Hyoglossus (see under extrinsic muscles of the tongue)

6. Mylohyoid (see under muscles that lower the mandible)

7. Medial Pharyngeal Constrictor (see under muscles of the pharynx)

8. Stylohyoid

Attachments: As the name implies, this muscle originates on the styloid process on the temporal bone. The fibers course inferiorly and anteriorly to insert in the greater cornu of the hyoid bone.

Function: Works with the posterior belly of the digastric to elevate and draw posteriorly the hyoid and with it the larynx. Because the fibers are attached to the greater cornu of the hyoid bone, contraction will cause the hyoid bone and the thyroid cartilage to tilt forward when the sternohyoid acts as a fixator. This may help bring the tongue forward for alveolar, dental and interdental articulations.

B. DEPRESSORS

1. Omohyoid

Attachments: This muscle's posterior belly originates on the upper border of the scapula, anterior belly on the intermediate tendon. The posterior belly inserts in the intermediate tendon, where the anterior belly takes over and runs vertically and slightly medially to the lower border of the greater cornu of the hyoid bone.

Function: The omohyoid lowers the hyoid and the larynx, similar to the sternohyoid.

2. Sternohyoid

Attachments: Sternohyoid attaches to the posterior surface of the manubrium of the sternum and the medial end of the clavicle. Fibers run vertically to the lower border of the body of the hyoid bone.

Function: The sternohyoid draws the hyoid bone inferiorly, which pulls the larynx forward, lowering F0 by increasing the superior-inferior thickness of the vocal folds. It also tilts down the anterior part of the hyoid bone for front articulations.

3. Sternothyroid

Attachments: This muscle attaches to the posterior surface of the manubrium of the sternum and the first costal cartilage. The fibers course superiorly and slightly laterally, inserting in the oblique line on the thyroid cartilage.

Function: The function of this muscle is under some dispute. Some investigators call it a hyoid depressor, others a larynx elevator, with some fibers also serving to stabilize, or perhaps raise, the thyroid cartilage.

4. Thyrohyoid

Attachments: This muscle attaches to the oblique line of thyroid cartilage. It runs vertically, deep to the omohyoid and the sternohyoid and inserts in the lower border of the greater cornu of the hyoid bone.

Function: On contraction, the thyrohyoid decreases the distance between the thyroid cartilage and the hyoid bone. When the thyroid cartilage is fixed, it depresses the hyoid bone. When the hyoid bone is fixed, it elevates the thyroid cartilage and raises the pitch. It also tilts the hyoid backwards, which may be appropriate for velar and uvular articulations.

VIII. INTRINSIC LARYNGEAL MUSCLES

A. SPHINCTER MUSCLES FOR LARYNGEAL INLET

1. Aryepiglottis

Attachments: This muscle attaches on the side of epiglottis. Fibers run from the sides of the epiglottis to the apex of each arytenoid.

Function: On contraction, the aryepiglottis pulls back the epiglottis (i.e. closes off the laryngeal inlet) by a sphincter action. This is to close off the laryngeal inlet for swallowing and may be used in production of lower pharyngeal articulations.

2. Thyroepiglottis

Attachments: Thyroepiglottis runs from the inner surface of the thyroid cartilage close to the angle superiorly and posteriorly to the aryepiglottic fold.

Function: This muscle depresses the epiglottis to close off the passage for swallowing. It probably has no function in speech.

B. ABDUCTOR

1. Posterior Cricoarytenoid

Attachments: This muscle attaches in the depression on the posterior surface of the cricoid cartilage. The fibers run superiorly and laterally to insert in the posterior surface of the muscular process of each arytenoid.

Function: On contraction, this muscle pulls the arytenoids inferiorly and medially on the shoulders of the cricoid cartilage and rotates them from lateral to posterior. The vocal processes are projected slightly upwards and abducted. EMG studies have shown activity in the production of voiceless stops and fricatives. These muscles are the sole abductors of the vocal folds

C. ADDUCTORS

1. Lateral Cricoarytenoid

Attachments: This muscle originates at the upper border of the arch of the cricoid cartilage. Fibers run superiorly and posteriorly along the rim of the cricoid cartilage to insert in the muscular process of the arytenoids.

Function: This muscle rotates the arytenoids inwards and downwards to approximate the vocal folds. When the vocal folds are already adducted, additional tension in the lateral cricoarytenoid will cause raising of the pitch. Further contraction is said to lead to a slight abduction at the arytenoid and of the folds--the proper position for the production of whisper.

2. Interarytenoids

a. Horizontal fibers (transverse arytenoid)

Attachments: Fibers attach to the posterior surface and lateral border of each arytenoid and the lateral edge and muscular process of the opposite arytenoid.

Function: On contraction, this muscle draws the arytenoids together by pulling them up on the shoulders of the cricoid cartilage and elevates them slightly. It may contribute to raisinf F.

b. Oblique arytenoid

Attachments: These fibers run from the lower posterior surface of each arytenoid and course superiorly and obliquely to insert in the apex and the lateral sides of the opposite arytenoid. The two sets of fibers cross each other.

Function: This muscle adducts the vocal folds by bringing the apexes of the arytenoid cartilages together. During forced contraction it can bring the false folds together for "ventricular voice". It also helps the aryepiglottis to close off the vestibule of the larynx.

D. TENSORS

1. Cricothyroid

Attachments: This muscle originates on the lower border and outer surface of the arch of the cricoid cartilage. The lower fibers run posteriorly and superiorly to insert into the anterior margin of the inferior cornu of the thyroid cartilage. The upper fibers course vertically upwards to insert into the inner part of the inferior margin of the thyroid cartilage.

Function: The basic function of this muscle appears to be to elongate and thus increase the tension in the vocal folds in order to raise the pitch. If the thyroid cartilage is fixed, it raises the anterior part of the cricoid towards the anterior part of the thyroid, while tilting the posterior part of the cricoid backwards. If the cricoid cartilage is fixed, the cricothyroid muscle tilts the anterior part of the thyroid cartilage downwards. In both cases, the distance from the angle of the thyroid cartilage and the arytenoids is increased, thereby stretching the vocal fold.

2. Vocalis

Attachments: Fibers originate in the posterior and inferior half of the angle of the thyroid cartilage. Coursing posteriorly, the fibers insert into the vocal processes of the arytenoids near the vocal ligament.

Function: The vocalis is actually part of the thyroarytenoid muscle. There is no physical

Appendix C: Annotated Bibliography

ABD-EL-MALEK, S. (1939). Observations on the morphology of the human tongue. Journal of Anatomy, 73: 201-210.

One of the best descriptions of the muscles of the tongue, based on dissections and experimental work. Most writers quote him. Contains a very good description of the septa of the tongue, usually not found in most anatomy books in such detail. The median, paramedian and lateral septa are described. Diagrams and plates support a very detailed description of the muscles of the tongue. Unfortunately, no attempt is made to suggest the way in which the muscles participate in the different movements of the tongue.

CLEMENTE, C.D. (1975). Anatomy: a Regional Atlas of the Human Body. Philadelphia: Lea and Febiger.

Beautiful, color illustrations created from clear, bold and complete drawings originally by the German anatomist Sobatta. Sequence goes from the pectoral region through the thorax, vertebral column and spinal cord, and, finally, the neck and head. Uses English rather than Latin labels, consistent with Gray's Anatomy. Illustrations with complex textural differences are often supplemented by schematic diagrams.

DABELOW, R. (1951). Vorstudien zu einer Betrachtung der Zunge als funktionelles System: II. Die Muskulatur und ihre bindegewebigen Insertionen (Preliminary studies of the tongue as a functional system: II. The musculature and its interdigitated insertion). Gegenbaurs Morphologisches Jahrbüch, 91: 33-76. (In German).

An anatomical investigation of human (as well as other mammalian) tongues, with many excellent photographs and diagrams. Disagrees with Abd-El-Malek (1939): "The [median] septum is no fibrous dividing wall but a complicated linkage of the transverse muscles. The longitudinal musculature consists of bow-shaped pieces which are shortest near the surface and get longer as they get farther towards the depth. Those even deeper are completed by styloglossus fibers." (Quote taken from English abstract.)

DIAMOND, M.C., SCHEIBEL, A.B. and ELSON, L.M. (1985). The Human Brain Coloring Book. New York: Barnes and Noble.

Good source for illustrations, and coloring in if you desire! Drawing by hand is another good method of appreciating how structures connect.

DICKSON, D.R. and MAUE-DICKSON, W. (1982). Anatomical and Physiological Bases of Speech. Boston: Little, Brown & Co.

Designed for both beginning and advanced students. Contains useful background information at the outset, then the same coverage as Dickson and Maue (above), but in greater textual detail, and with an additional chapter on the nervous system. Much attention given to basic principles of structure and function of neuromuscular system in order to better understand the physiology. Many invaluable diagrams and photographs.

HARDCASTLE,W.J. (1976). Physiology of Speech Production: an Introduction for Speech Scientists. London: Academic Press (London) Ltd.

Includes several excellent schematic diagrams of complicated muscle interactions and

concrete discussion of physiological correlates of traditional speech sound categories (i.e. stop, fricative, tap, trill, etc.). Several chapters are organized around muscles involved in particular actions, their attachments, innervation, etc.

HILL, K. (1964). The musculature of the tongue. UCLA Working Papers in Phonetics, 1: 22-39.

Simple overall description of the suprahyoid muscles, the intrinsic muscles of the tongue, the extrinsic muscles of the tongue, and the connective tissue structure of the tongue. Explanations in the text are very thorough , intelligible and helpful for comprehending the composition of the tongue and surrounding framework. Fourteen figures and and extensive annotated bibliography.

KAHANE, J.C. and FOLKINS, J.W. (1984). Atlas of Speech and Hearing Anatomy. Columbus: Charles E. Merrill.

A unique and comprehensive book of photographs from anatomical specimens. Some are fiberoptic while others come from dissections and photomicrographs. Actual preparations are largely favoured over drawings, but occasionally drawings and illustrations are taken from the literature to clarify certain anatomical concepts. Fascinating, and essential for this course.

MATT, M. and ZIEMIAN, J. (1990). Human Anatomy Coloring Book. New York: Dover.

Designed for use by high school teachers, but nevertheless another useful source for clear and easy-to-adapt illustrations. Entertaining and instructive guide to the human body—bones, muscles, blood, nerves, and how they work.

MIYAWAKI, K. (1974). A study of the musculature of the human tongue: observations on transparent preparations of serial sections. Annual Bulletin, Research Institute of Logopedics and Phoniatrics, University of Tokyo, 8: 23-50.

Thorough description of muscles of the tongue. Then three tongues dissected in three planes: sagittal, coronal and transverse. Sections made transparent, revealing the direction of the muscle fibres very clearly. Complete series of drawings then made from the sections. The paper also contains a mini-bibliography relating to the tongue.

NETTER F. H. (1997) Atlas of Human Anatomy. 2nd edition. East Hanover, N.J. : Novartis.

Beautifully illustrated and extraordinarily detailed anatomy atlas. We recommend that you have this atlas on-hand during dissection.

PERNKOPF, E. (1989). Atlas of Topographical and Applied Human Anatomy. Vol. 1, Head and Neck. Philadelphia: Williams & Wilkins.

Pages 136-141 have very useful pictures of the tongue, its muscles, and the area around it. No text.

SEIKEL, J. A., KING, D.W., and DRUMRIGHT, D.G. (2000). Anatomy and Physiology for Speech, Language, and Hearing. San Diego: Singular.

A basic anatomy and physiology textbook aimed at the speech and hearing science student. Contains thorough explanations of muscular function as well as clear illustrations of the

muscles and bones.

STRONG, L.H. (1956). Muscle fibers of the tongue functional in constant [sic] production. Anatomical Record, 126: 61-79.

An important article, illustrated with excellent photographs of sections of the tongue. Carries on the work of Strong and Gold (1950), investigating how the intrinsic tongue musculature would deform the tongue to conform to the outlines of palatograms. Rather naive about palatograms and tongue positions, confusing hypothesis concerning the action of the transverse and vertical muscles which are supposed to act in a special way in consonants. Interesting critical review of the anatomical literature, showing some of the nineteenth-century sources of Gray, Cunningham and Spalteholtz. Mentions existence of Abd-El-Malek (1939), but pays no attention to his work. The word "constant" in the title (and one line of the article) is a typographer's error, corrected in an Erratum in a later issue; Strong intended "consonant".

ZEMLIN, W.R. (1997). Speech and Hearing Science. 4th edition. Boston: Allyn & Bacon.

Excellent descriptions of speech organs' physiology and pathologies. Written for the speech science audience.