REVIEW TOPICS

1. Describe the process of tasting, and tell how smell influences the sense of taste.
2. Give the use of the sense of taste.
3. Describe the endings of the nerves of smell in the nose, and tell how the sensation of smell is produced.
4. Give the use of the sense of smell.
5. Describe the inner ear: its cochlea, semicircular canals, and nerves of hearing, and tell how they act.
6. Describe the middle ear: its bones, the two membranes which close it, and its Eustachian tube.
7. Show how a stoppage of the Eustachian tube may lead to deafness; to running ears.
8. Show how throat trouble may cause ear disease.
9. Tell how to care for running ears.
10. Show why boxing the ears is dangerous.
11. Describe the outer ear: its air passage and wax.
12. Show how the ears may seem to hear sounds which do not exist.
13. Describe the ear in a frog; in a snake; in a fish; in a lobster.

CHAPTER XXXV

THE EYE

604. Light. — Straight lines of light called *rays* pass off from objects in all directions. Each ray is supposed to be a vibrating line in a thin substance called ether, which fills all space.

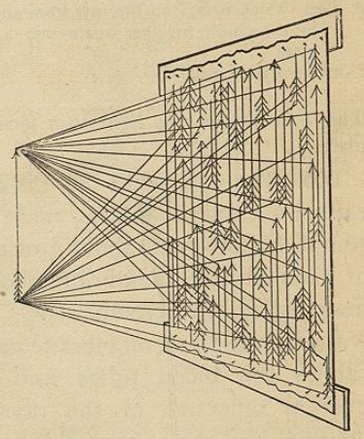


Diagram of light passing from an object.

It passes in every direction, and, falling upon a screen, produces a confused multitude of images, which form only a mass of light, but no one clear image.

The vibrations of ether take place many millions of times each second. In sound the air vibrates only a few hundred times. Light travels nearly 185,000 miles each second, while sound travels about 1000 feet in the same time. Light waves are from $\frac{1}{30000}$ to $\frac{1}{60000}$ inch in length, but each sound wave reaches several feet. The length of a wave of light determines its color. Red waves are about twice as long as violet waves. A mixture of all colors produces white light, while black is due to the absence of light. Colors which, like red and green, form white light, are called *complementary* colors.

In passing through glass or other clear substances, rays of light may be bent from their courses. By a properly shaped glass called a *lens*, rays may be spread apart or may be brought together in a point called

a *focus*. If the focus falls upon a screen, an image of the object giving the light will appear. By changing the kind and the position of the lens the image may be made either larger or smaller than the real object.

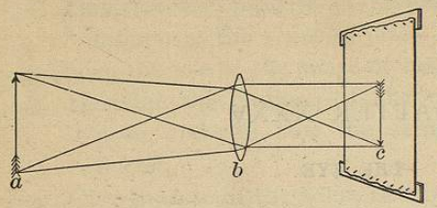


Diagram of the formation of an image with a lens.

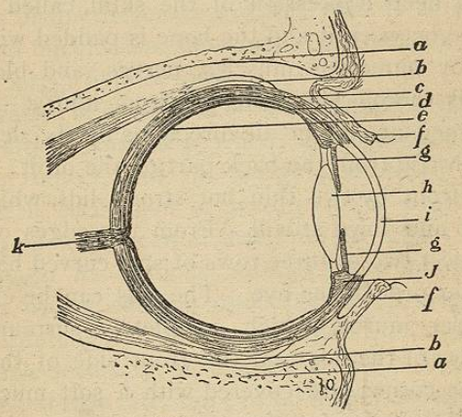
a an object sending off light.
b a lens which brings all the rays from any point in the object together again into a single point.
c image of the object *a*.

Light has the power to produce a chemical change in substances. Photography and bleaching clothes are examples of the action of light. In photography a prepared plate is inclosed in a tight black box, into which light from an object is admitted through a small lens. The lens brings the light to a focus and forms an image upon the plate.

605. The eye. — The eye is an apparatus like a photographer's camera, but is more perfect. It consists of a round, hollow shell about $\frac{3}{4}$ of an inch in diameter, formed of a very tough membrane about $\frac{1}{16}$ of an inch in thickness, called the *sclerotic coat*. The sclerotic coat is lined with a thin black membrane called the *choroid coat*, which carries the blood tubes, and is colored black so as to prevent reflection of the rays of light. Inside of the choroid coat is a very thin and transparent membrane called the *retina*. The cavity of the eyeball is filled in front with a thin, clear liquid called the *aqueous humor*, while its back part contains a thick, jellylike fluid called the *vitreous humor*. The two humors keep the eyeball distended and in shape.

The nerve of sight, called the *optic nerve*, enters the back part of the eye and separates into fine threads which end in microscopic rods set closely together on their ends

in the retina. The retina corresponds to the photographic plate of a camera. A bulging transparent tissue, called the *cornea*, forms a round window through the front part of the eyeball, and admits light to the retina. Behind the cornea is hung a curtain called the *iris*, in whose center is a hole called the *pupil*. The iris is colored to a shade



The human eye.

a bone of the orbit.
b muscle which moves the eyeball.
c sclerotic coat.
d choroid coat.
e retina.
f eyelid.
g iris.
h lens.
i cornea.
j muscle which changes the shape of the lens.
k optic nerve.

varying from blue to dark brown, and it is this which gives the color to the eye.

The iris is composed of muscle fibers which can contract so as to make the pupil smaller. A strong light acts in a reflex way to cause the iris to contract and make the opening of the pupil smaller, but in a dim light the pupil is large, so as to admit all the light possible. Thus the iris regulates the amount of light admitted to the retina.

606. Sight. — Behind the pupil is a lens whose shape can be changed at will by the action of muscles. The

lens brings the light to a focus so as to form an image of an object upon the retina. In the cells of the retina are particles of brown coloring matter in which light produces an instant change. This excites in the optic nerve an impulse which the brain interprets as sight.

607. Coverings of the eye. — The eyeball is loosely situated in a deep depression of the skull, called the *orbit*. The space between it and the bone is padded with fat and crossed by numerous muscles, nerves, and blood tubes. Thus it is thoroughly protected from injury. It can be freely turned at will in all directions by six slender muscles which rise from the back part of the orbit. It is protected in front by two thin but strong lids, which can be moved up and down at will. From the edges of the lids there project two or three rows of stiff curved hairs, which still further protect the eye. The lids can be closed by a flat circular muscle which completely surrounds them. The insides of the lids and the front side of the eyeball, except the cornea, are covered with a soft mucous membrane, called the *conjunctiva*.

608. Tears. — The conjunctiva and cornea are moistened by a saltish fluid called *tears*. Tears are secreted by a gland called the *lachrymal* gland, which is situated just above and to the outer side of the eyeball. At the inner end of the edge of each lid is the opening of a small tube which unites with the tube from the other lid and forms a single tube called the *nasal duct*, leading to the nose. Ordinarily the nasal duct drains away the tears as fast as they are formed, and sometimes, as in crying, their salt taste can be noticed in the mouth. Often they are produced so fast that some run over the lids and fall down the face. The uses of tears are to wash away particles of dust which fall upon the eyeball, and to moisten its surface.

609. Field of view. — A person can clearly recognize objects in only a small part of the field of view just in front of the eyes, while the rest seems to be only indistinct shadows. To be distinct, the image must fall upon the part of the retina less than $\frac{1}{8}$ of an inch across, which is situated directly behind the cornea. In reading a book, the eye can distinctly see two or three words at once, but by rapid and unconscious movements of the eyes sidewise, we cover a larger field of view.

610. Duration of sensations. — The sensation of sight is produced almost instantly when the eyes are directed towards an object, but the image persists for $\frac{1}{10}$ of a second. If a succession of pictures of a moving object are thrown upon a screen at that rate, the object will seem to go through its motions without interruption. Birds flying and waves dashing upon the beach may be thus shown absolutely true to life. A point of light swung about a circle seems to be a shining ring. If two colors are revolved at that rate, the eye no longer sees either one, but a mixture of the two. Thus a blue and a yellow spot side by side, when revolved before the eye, seem a single green spot.

611. Color blindness. — Sometimes the nerves of the retina are unable to recognize certain colors. In the most usual form of color blindness red is supposed to be green or gray. In locomotive engineers and sailors color blindness may be a serious defect, for they are guided by different colored signals, especially those containing red.

612. Exhaustion of the retina. — When the eyes look steadily at objects for a long time the vision becomes blurred. If one gazes steadily at a bright colored object, the retina is fatigued by that color. A white object looked

at now will show a colored spot shaped like the first object, for a part of the retina is no longer able to recognize all the colors which make white light. Its color will always be complementary to the color of the object first looked at. Thus when a red object is used first, a green image appears. The eye is really made color blind for a brief period.

Ordinary lamps and gas jets give a yellowish light, while the sunlight is white. So by lamp light, the colors of objects seem to be changed. In incandescent electric lamps the light is given off from a white-hot filament. Owing to its steadiness, its color and the absence of heat and foul gases, it is the most agreeable light in common use.

613. Care of the eyes. — No light should be strong enough to dazzle the eyes. When, as in public halls, bright lights are in front of the eyes, there is a natural tendency to gaze directly at them, thereby tiring the retina. It would be better to look at the darkest objects in the room.

It is best to have the light come from behind the eye. In working with a lamp in front of the eyes, a shade should cover either the light or the eyes. When the sun shines brightly upon the snow the excess of light exhausts the retina. Then the eyes become painful, and blindness may result.

614. Contraction of the pupil. — A strong light excites the reflex center in the optic tubercles to send out an order for the contraction of the muscles of the iris so as to make the pupil smaller. On the other hand, in the dark the pupil is large, so as to admit all the light possible. When a light is very strong, the reflex centers send orders to the muscles both of the upper and lower lids, and of the eyebrows to pucker themselves over the eyes, so as to leave only a narrow slit for the entrance of light. In this way the eyes are well protected against too strong lights, but the contracted muscles may become tired and painful.

615. Accommodation. — Rays of light coming from a distant object are less diverging than when coming from one near by; then the lens does not need to bend them so much as in seeing objects near by. Adjusting the lens of the eye to near or far vision is called *accommodation.* When the eye muscles are at perfect rest, the eye is accommodated to see clearly at all distances over twenty feet. So distant vision requires no effort. When one wishes to see an object less than twenty feet away from the eye, the muscles must cause the lens to become more curved. Thus the eye can see clearly up to about five inches from the eye. Vision is best when the object is about ten inches from the eye.

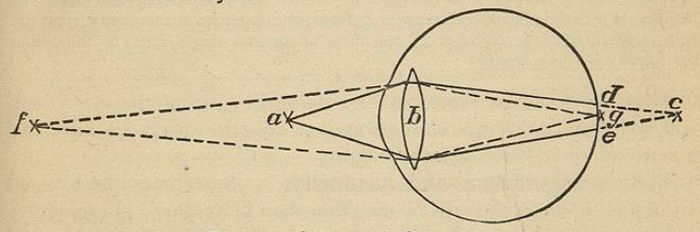


Diagram of the eye in far sight.

The lens *b* does not bring the rays from a point of light *a* together soon enough. So the rays fall over the whole surface of the retina from *d* to *e*, making a confused image instead of a clear point. When the rays spread less apart, as when the light is moved farther away, to *f*, the lens brings them together sooner. Then the rays fall upon a single point of the retina at *g*, and thus form a clear image.

616. Far sight. — At the age of about forty-five, the muscles of the lens lose some of their power of contraction and are unable to make the lens so curved as in youth. Then the eye cannot be adjusted for near vision, while for far vision the sight is as good as ever. So an old man holds his newspaper at arms' length. He also aids the action of his lens by placing before his eye a spectacle lens which corrects the deficiency in the lens of his eye.

617. Near sight. — In young people the lens often brings the rays together too soon. The rays must be made more diverging by

bringing the object very near the eye. Such persons cannot see distinctly at a distance greater than a few inches, but walk about as in a perpetual fog.

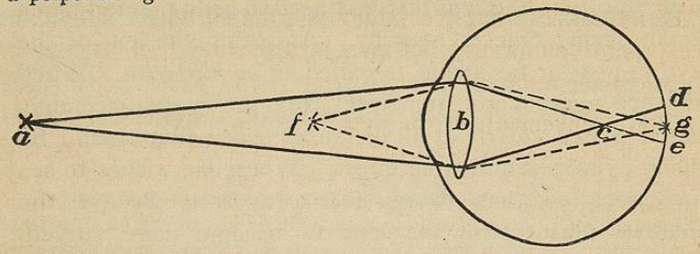


Diagram of the eye in near sight.

The lens *b* brings the rays from a point of light *a* together at *c* too soon. So the rays cross and fall over the whole surface of the retina from *d* to *e*, making a confused image instead of a clear point. When the rays are spread apart by bringing the light near the eye, as at *f*, they come together farther away upon the other side of the lens, as at *g*. Thus they fall upon a single point of the retina and produce a clear image.

Near sight can be remedied by placing in front of the eye a lens which will make the rays more diverging. So the spectacles have the glasses hollowed out instead of bulging.

618. Astigmatism and headaches. — Sometimes the lens or cornea is more curved in one direction than in another. Then a part of the object will seem distinct, and another part blurred, and the eye muscles will constantly change the focus in the attempt to obtain a full and clear image. This is very tiresome to the eyes, and often causes severe headaches. The remedy is to use a glass which is curved in one direction only, so as to correct only the defective part of the lens.

619. Cataract. — Sometimes the lens becomes hard and white. Then no light can pass through, and there is total blindness. This is called a *cataract*. By a simple and safe operation the lens can be removed, when the light will fall upon the retina as before. Spectacles to take the place of the lens enable the person to see.

620. Judgment of position. — In perfect vision each eye is turned toward the same point, so that the images fall upon corresponding points of the retina. But the two eyes view an object from different positions, and so the images

are not exactly alike. The blending of the images will give the idea of solidity or of position in distinction from the impression that everything is a flat surface. This perception is not natural, but must be learned. Distant objects always seem flat.

621. Movements of the eyes. — If the images of an object do not fall upon corresponding parts of the retinas of the two eyes, two images will be seen. Sometimes a muscle will draw one eye aside so that it does not look in the same direction as the other eye. A person with this defect is said to be cross-eyed.

Young babies have no control of their eye muscles, and so have no distinct vision, except as they catch accidental glimpses. A bright cloth gives them a sensation of color at whatever distance it is held, and so amuses them. At about the age of three months they begin to gain control of their muscles, so that they can focus the eyes and turn them to any object at will. It takes them several months more to acquire a knowledge of solidity and position.

Anything touching the eye causes the lids to close in a reflex manner for protection. Tears flowing over the eye cause the lids to wink and distribute the moisture over the whole surface.

In reading in the cars, the constant jarring of the paper compels the muscles of the eyes to be in constant action to adjust the eye to the ever-varying positions and distances. So they soon become tired and ache. In reading while lying down, the eyes must look toward the feet. The constant strain of turning the eyes down tires the muscles, so that the vision becomes blurred.

622. Diseases of the eye. — An ulcer or scar upon the cornea, closure of the pupil, cataract, and wasting of the optic nerve are common causes of blindness. The conjunctiva of the lids may become inflamed and run matter, or may become raw as in *granulated* lids. All matter should be kept from the eye by washing it off with borax water.

A particle of sand or other substance between the eyeball and the lids causes great pain. Rubbing the eyelid forces the particle into the delicate flesh and increases the pain. If the lid is gently held away from the eyeball for a moment, the tears may wash out the particle.

Blows upon the eye are seldom dangerous, for the sclerotic coat is the strongest tissue in the body.

623. Illusions of sight. — Irritating the optic nerve excites the sensation of light. A blow upon the head causes a sensation of seeing bright stars. Pressure upon the eyeball causes a sensation of a ring of light.

In dreams, sight memories return to consciousness with all the vividness with which they were first made. A crazy man may imagine the face of the clock to be a man's face mocking him, and so he may attack and destroy it. To insane persons of a religious turn of mind, a cloud may seem to be an angel urging them on to some inspired mission.

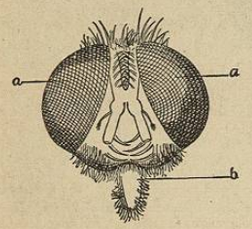
624. Effects of alcohol and tobacco. — *Alcohol* weakens the optic nerves, and tends to cause dimness of vision while the eyes may appear healthy. Tobacco has a still greater effect upon the optic nerve.

625. X rays. — In December, 1895, a kind of light produced by electricity was discovered which can penetrate wood, flesh, and other substances. By means of it photographs can be taken. Although it makes no impression upon the retina, yet by passing it through certain substances the rays become visible to the eye. Bone is penetrated by the rays with greater difficulty than flesh, and so they can be photographed and seen within the body. These rays cannot be bent from their course, and so cannot be brought to a focus to produce a real image; but images of objects are formed in shadows, due to the varying degrees of light which passes through different objects. The rays are sometimes called Röntgen rays from their discoverer, and sometimes simply X rays because of their unknown nature. Practical use of the rays is made in looking within the body so as to determine by sight the condition of the bones and the location of substances imbedded in the flesh.

A foot in a shoe.
(From an X ray photograph.)

626. The eye in lower animals. — In all fourfooted animals, and in birds, reptiles, and fishes, the eyes are essentially the same as in man.

Most *insects* possess large immovable eyes shaped like a dome. Each eye is made up of many smaller eyes like a honeycomb. Each little eye contains a lens which forms an image upon the nerve at the bottom of the cavity.



The eye of a house fly.
a eye, made of many small eyes. *b* mouth.

In some lower forms of animals, like the leech, there is a spot of dark coloring matter under the skin in which the nerves of sight end. Such eyes cannot form an image, on account of the absence of the lens, but a bright light or a shadow of a large object can affect the nerve and give the leech some idea of its surroundings. Some still lower forms of animals seem to be able to recognize light, for they fold themselves up when darkness comes, and yet they have nothing which at all resembles an eye.

Some plants, like the morning glory, are affected by light, for their flowers fold themselves at night and open again when the sun rises.

SUMMARY

1. Light is the name given to the vibrations of a very rare gas which fills all space.
2. The eye is like a photographer's camera.
3. The eye is set deep in a bony socket, called the *orbit*, and is protected in front by the *lids*, and moistened by *tears*.
4. The eye can see distinctly only a small space directly in front, but can distinguish the presence of objects in a full half circle.
5. A sensation of sight is produced instantly, but persists for one tenth of a second after the light disappears.
6. Some eyes cannot see some colors, especially red.

7. If the lens cannot bring the rays of light together, a person is *far-sighted*, but if it brings the rays together too soon, he is *near-sighted*. If it brings some of the rays together sooner than others, the condition is called *astigmatism*.
8. If the lens does not permit light to pass through, the condition is called a *cataract*.
9. By means of the two eyes viewing an object from slightly different positions, we form an idea of position and solidity.
10. If one of the muscles of the eye pulls the eyeball to one side, the person is *cross-eyed* and sees two objects instead of one.
12. Irritation of the optic nerve causes a sensation of sight as though light had caused the impression. Memories of sight may be recalled so vividly as to seem real, as in a dream.

DEMONSTRATIONS

135. Examine the eyeball of a calf in its socket. Carefully separate the eyeball and its muscles and nerves from the fat. Notice the cushion of fat surrounding the whole eyeball. Notice the slender muscles which arise from the back part of the orbit and are attached to the outer edge of the eyeball. Notice the optic nerve entering the middle of the back side of the eye. Notice other nerves and the numerous blood tubes which cross the space. Preserve the specimen in Müller's fluid.

136. Procure several eyes removed from their sockets, and place some in Müller's fluid for a week or two, and examine others fresh.

Notice the bulging and clear cornea, and the tough white sclerotic coat. Holding the eye with its cornea toward you, cut it completely into halves. Notice the aqueous and the jellylike vitreous humors. Notice the curtain of the iris and its pupil. Behind the iris notice the lens. Remove the lens and note its shape and its firm consistency Notice the black choroid coat lining the eyeball next to the sclerotic. Notice the thin retina, which readily separates from the choroid.

137. With a common magnifying glass show how a convex lens brings rays of sunlight to a focus. Show also a photographer's camera. Show the image which appears upon the ground glass. Then compare the camera with the eye specimen, pointing out the resemblances.

138. Have the students look steadily at a line of print and tell how much they can read without moving their eyes. An inch and a half will be all they can see at once.

Next have them look steadily at an object, and notice how they can see dimly all objects in a semicircle about them.

139. Illustrate the duration of impressions by spinning a square top. It will appear circular.

140. Illustrate the exhaustion of the retina by having the students gaze at a square of black cloth upon a white paper. After a moment let the students look steadily at the wall, when a square spot of light will appear, for the part of the retina upon which the image of the cloth fell is less exhausted than the rest, and so it sees the light from the wall more clearly.

141. Illustrate color blindness by taking a sheet of light pink paper. Have the students first look steadily at a bright red object in a strong light. Then gaze at the pink paper; a *green* image of the first object will appear, showing that a part of the retina has become exhausted for the red rays, but can still see other colors.

142. Notice the pupil of the eye and its varying size in different lights. Shade another person's eyes with the hands, and, quickly removing them, notice that the pupils grow smaller. Have a person look steadily at your finger held a few feet in front of the eyes, and then quickly bring the finger near the eye and notice that the pupil contracts while looking at it near by.

143. Illustrate a near-sighted eye by holding a magnifying glass in front of the eye, which is the same as increasing the power of the lens. Notice that the object must be brought nearer the eye.

Show a double concave lens and explain that it scatters rays and so is used in glasses for near sight.

144. Illustrate far vision by looking through two magnifying glasses of different strengths. Notice that the weaker glass must be held farther away from the object.

145. Place a book edgewise before the eyes and notice that one eye sees one side and the other eye the other side.

Now examine a stereopticon photograph of a statue, and notice that the two pictures are not exactly alike. When the views are blended into one by the stereopticon, the image seems to stand out like a real statue. Explain that in this way the two eyes gain a knowledge of position and solidity.

146. Illustrate double vision by pressing one eyeball aside while looking at an object.

147. Have a person gaze at your finger held at a distance from his eye. Now bring the finger near the eye, and notice that the eyes each turn towards the nose so as to keep directed toward the object. This is the only manner in which we can move the eyes in opposite directions.

148. Press hard upon the closed eyelids. Notice the ring of light which appears. Explain that this is due to the irritation of the optic nerve.

149. Test the individual members of the class for color blindness by showing them shades of red, green, and yellow, telling them to match the shades and arrange them in order. Also test the power of vision of the individual members of the class by placing before them printing with letters of various sizes. Have each pupil read as far as he can, all standing at the same distance.

REVIEW TOPICS

1. Describe light; color; focus; and the effects of light in a photographer's camera.
2. Show that the eyeball is like a photographer's camera, describing its outer coverings; its retina; nerve; cornea; iris, pupil, and lens.
3. Describe the orbit; eyelids; the lachrymal gland; tears, and the tear ducts.
4. Show that a person can see more clearly directly in front of his eyes than upon either side.
5. Show that the duration of a sight sensation changes the appearance of moving objects.
6. Describe *color blindness*.
7. Show that the retina may become unable to act from overwork, as by gazing at bright objects; at colored

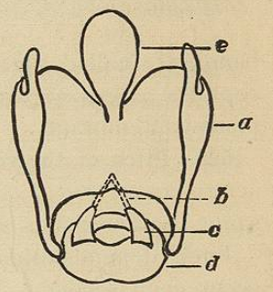
objects; and by a light in front of the unshaded eyes.

8. Show that the iris protects the retina against too strong light.
9. Show that the lens must change its shape to accommodate itself to near vision and to far vision.
10. Tell the condition of the lens and the remedy in *far* sight; in *near* sight; and in *astigmatism*.
11. Describe a cataract and its remedy.
12. Show how two eyes aid in the judgment of form and position.
13. Describe the condition of the eye muscles in a cross-eyed person, and tell how vision is affected.
14. Show how reading upon a moving railway train and reading while lying down overwork the eye muscles.
15. Tell how to care for an eye which runs matter, and how to remove a speck of dirt from under the lid.
16. Show that rubbing a sore eye is always liable to do harm.
17. Show that irritation of the eye may produce false sensations of sight; and that sight memories may seem to be real again.
18. Describe the *X rays*.
19. Describe the effects of alcohol and tobacco on the eye.
20. Describe the eye in lower animals; in insects; and in a leech.

CHAPTER XXXVI

THE VOICE

627. The larynx. — The basis of the voice is a sound made in the larynx during expiration. The larynx is a triangular box about three quarters of an inch across, made of cartilages. It connects the trachea and pharynx. Its two sides are formed of a flat cartilage, bent sharply backward, and called the *thyroid* cartilage. The upper end of the fold projects slightly from under the chin and is called the *Adam's apple*. Underneath the thyroid cartilage is a circular cartilage whose back part projects upward so as partly to fill in space between the back edges of the thyroid cartilage. In form and size it resembles a large finger ring, and is called the *cricoid* cartilage.



Back view of the larynx.

a thyroid cartilage.
b vocal cords.
c movable cartilage for the attachment of the vocal cords.
d cricoid cartilage.
e epiglottis.

On top of the back part of the cricoid cartilage are two small cartilages, shaped like triangular pyramids, and so arranged that they can turn sidewise. One lower corner of each projects forward. From it a flat band extends across the larynx, and, with its fellow from the opposite side, attaches itself to the lower part of the thyroid cartilage. Muscles can tighten them and bring them close