INTRODUCTION

This course has been designed to be applicable for you if you have experienced a loss of vision, if you have a child who is visually impaired, or if you work with individuals who are visually impaired, whether they are children or adults. Broad information is presented to enable you to understand many eye conditions and to formulate questions to ask your own health care provider regarding your specific situation.

In the first three lessons, concise and clear information is given describing the general anatomy and function of the parts of the eye, how these parts all work together, and how eyes are examined and vision is tested in an eye doctor's office.

The remaining seven lessons center around a particular part of the visual system. Each one begins with objectives specific to the topic covered, followed by information relating to more detailed anatomy, diseases or related conditions and their treatments, and practical implications of each disease or related condition.
Your answers to the Practical Application questions do not need to be returned to your instructor. They are designed so that you can apply what you have learned to your own situation. Lesson assignments to evaluate your comprehension of the material presented should be answered in the medium of your choice—print, braille, or cassette—and mailed to your Hadley instructor.

The nature and intent of this course are to provide a broad base of understanding. Although many different common diseases are briefly described, you are encouraged to pursue further study of the particular eye condition that affects you or your family and to formulate specific questions to ask your own physician or eye doctor. Words that may be unfamiliar appear in bold the first time they are used in the text and are defined at the end of the lesson or in the glossary at the end of the text. A list of references for further study is also included.

The authors of this revised and updated course wish to express their appreciation to Dr. Thomas Chalkley, an ophthalmologist and author of the original 1982 book Your
Eyes, upon which these lessons are based. They also appreciate the thoughtful review of the manuscript by Dr. Steven V. L. Brown.

Feel free to contact your instructor through the toll-free number at The Hadley School for the Blind if you have questions about the course. That number is 1-800-323-4238. The Hadley faculty and staff are ready to provide you with encouragement and support as you work your way through these lessons.
LESSON OBJECTIVES

After studying this lesson you will be able to:

1. Describe the six muscles that control eye movements;
2. Define depth perception, convergence, divergence, and diplopia;
3. Discuss the causes and treatment of amblyopia; and
4. Discuss the causes and treatment of strabismus.

WHAT ARE THE EYE MUSCLES AND WHAT DO THEY DO?

All of the movements of the eyes are controlled by six rectangular-shaped extraocular muscles which are attached to the outside of each eye. One end of each of the four rectus (straight) muscles is attached at the back of the bony socket in a little circle surrounding the optic nerve. The other end of each muscle runs forward and inserts into the tough sclera of the eye, 6 to 7 mm (about 1/4 inch) from the border of the cornea. The oblique
(slanted) muscles differ from the rectus muscles, because they enter from the nasal side of the orbit and attach at an angle to the sclera. Together or alone they control all possible eye movements.

The six muscles shown in Figure 14 are:

1. The **medial rectus**, located on the inner side of the eye toward the nose, turns the eye in toward the nose.

2. The **lateral rectus**, located on the outer side of the eye toward the temple, turns the eye outward, away from the nose.

3. The **superior rectus**, located on top of the eye, primarily allows the eye to look up, but it also helps the eye turn inward and rotate.

4. The **inferior rectus**, located on the bottom of the eye, primarily allows the eye to look downward but it also helps the eye to turn inward and rotate.

5. The **superior oblique**, located on the top of the eye but slanting back at an angle, primarily rotates the eye in its socket, but also controls movement of the eye down and outward from midline.
6. The **inferior oblique**, located on the bottom of the eye but slanting back at an angle, is responsible for tilting the eye outward and raising the eye. When the medial rectus contracts, the lateral rectus relaxes. When the inferior rectus contracts, the superior rectus relaxes. When both eyes turn in any direction, they must turn an equal amount in order to maintain binocular vision (discussed later in this lesson). Equal nerve stimulation results in both eyes moving equal amounts.

**Figure 14. Muscles of the Eye**

The left eye, which is facing you, is represented by concentric circles in the center of the page. The smallest circle represents the pupil, the middle circle represents the iris, and the largest circle represents the outer edge of the eyeball.

The muscles are shown where they attach to the eyeball. Starting at the top right of the eyeball and going clockwise around the large circle:

1. The thickened area or bulge at the top represents the superior rectus muscle.
2. The bulge at the right side shows where the lateral rectus muscle attaches to the eyeball.

3. The large raised structure starting below the lateral rectus muscle and continuing toward the lower left corner of the page represents the inferior oblique muscle. Note that where that muscle attaches to the eye socket is not shown.

4. The bulge at the bottom of the eyeball represents where the inferior rectus muscle attaches to the eyeball.

5. The bulge at the left side of the eyeball represents where the medial rectus muscle attaches to the eyeball.

6. The thick line that forms a triangle at the upper left of the figure represents the superior oblique muscle hooked to its pulley.

[End of figure description.]
Innervation

The nerves which control the movements of the eyes through these six muscles are the third, fourth, and sixth cranial nerves. The third cranial nerve innervates or stimulates the medial, superior, and inferior rectus muscles as well as the inferior oblique muscle. It is the same nerve that supplies the ciliary muscle with its power to accommodate, or change the shape of the lens to focus a clear image on the retina. The sixth cranial nerve supplies the lateral rectus muscle and is solely responsible for the abduction of the eye, or turning away from the nose. The fourth cranial nerve innervates the superior oblique muscle.

Of the three cranial nerves controlling ocular movements, the third cranial nerve is the most important. It affects accommodation (ability to shift gaze from distance to near) as well as contraction of the medial rectus muscle. This results in the eyes converging or turning toward each other. Because of this, there is a definite relationship between a person's ability to accommodate and to converge. Usually, if an individual
tends to overaccommodate, the eyes will tend to overconverge and align at a point much closer to the face than the object actually is. This is the mechanism that most frequently causes crossing of the eyes.

Any damage to these nerves from trauma, infection, or blood vessel disease will affect the ability to move the eyes. Some diseases such as multiple sclerosis or tumors may also involve the cranial nerves. Lesions or injuries to the third cranial nerve will affect the ability to raise the upper eyelid, and the pupil may be dilated and unresponsive to light.

DEPTH PERCEPTION

**Binocular vision** is the blending of two separate, unidentical images (one in each eye) into one composite image. The binocular visual system, when functioning properly, allows three-dimensional viewing of objects and gives a feeling of depth and solidness. This **depth perception**, or the ability to see the relative spatial location of objects, is extremely important for many activities, such as shooting a basketball. Without both
eyes working together, clues about distance and depth are minimized. Depth perception is also important when judging approaching objects, such as a ball being thrown or a staircase that lies ahead. Judging the distance between your car and other moving vehicles requires good depth perception.

When an object is viewed, the eyes must do two things. First, they must align properly, with both eyes pointing toward the same point, and then they must focus on the object being viewed. Any disorder which disrupts proper alignment or focusing ability will compromise vision. An individual with usable vision in only one eye will need to learn to compensate for lack of depth perception.

CONVERGENCE AND DIVERGENCE

Turning the eyes inward toward each other in an effort to maintain binocular vision as an object is brought closer is called convergence. Turning the eyes outward or away from each other when viewing an object in the distance is referred to as divergence.

Some eyes cannot comfortably converge when viewing a near object, a condition referred to as convergence
insufficiency. The eyes converge behind the viewed target. Symptoms of this condition may include words appearing to run together when reading, headaches following near work, intermittent double vision with near work, a pulling sensation, and loss of concentration. Possible causes include a congenital weakness of the medial rectus muscles, head trauma, or a systemic disorder. It is also possible for the eyes to overconverge, or to converge in front of the target. This also causes blurred vision, double vision, and eyestrain after prolonged near work.

Divergence insufficiency is a misalignment of the eyes when viewing distant objects. With divergence insufficiency, the same phenomenon occurs as in convergence insufficiency, although the target is farther away. The eyes overconverge and align in front of the distant target. Symptoms may include intermittent blurred or double vision when viewing a distant object, and headaches around the eyes.
DOUBLE VISION OR DIPLOPIA

Good vision includes the ability of both eyes to work as a team and aim at the same object simultaneously. If they do not, diplopia or double vision will be present, an uncomfortable situation which causes the brain to suppress or block out the image of one eye.

It is possible that one eye, although it may be parallel during distance vision and converge for near vision, may point higher than the other. If this happens, the eyes will now actually perceive two different images. One eye will see the targeted object and the second eye will be pointing toward some other spot in the visual field, at a point higher than the targeted object. If both eyes are functioning normally, the result will be double vision, because one image will fall on the macula of one eye and the other, slightly off-center image will fall on the macula of the other eye.

For example, if John's face appeared on the right macula and Susan's face on the left, it would be difficult to decide whether you saw John or Susan, because the brain superimposes the image of each face, and the result is
double vision, or diplopia. This causes considerable confusion and is extremely annoying. The brain will compensate by unconsciously suppressing one of the images.

This phenomenon of double vision occurs most often in very young children who adapt easily to almost any situation. Instead of struggling with the two images, a child with double vision tends to favor one eye over the other. The image from the unfavored eye will be suppressed or disregarded, and only one face, not the superimposed faces, will be seen. This will work, but the side effect will be an inability to fuse images in order to perceive a three-dimensional picture. Parents may notice that the child's eyes seem to be pointing in different directions, especially when tired or after an illness. They may also notice that the child blinks a lot, moves the head from side to side to block out double vision, or holds objects up to one eye only.
Strabismus

Strabismus (struh-BIZ-mus), also referred to as squint or tropia, is a misalignment of one eye in any direction, horizontally or vertically. It is present in about 2 percent of children. The eye can turn inward (esotropia) (ee-soh-TROH-pee-uh) or outward (exotropia) (eks-oh-TROH-pee-uh). One eye can point higher than the other (hypertropia). (The term hypotropia is not used.) The misalignment can be present all of the time or some of the time. The strabismus can also be either unilateral (one eye) or it can be alternating, with first the right eye turning in, and then the left. Alternating, intermittent eye turns are usually less detrimental than unilateral, constant ones, because both eyes are still being used.

A person who has strabismus initially has diplopia. Since seeing double or diplopia is extremely disconcerting and uncomfortable, the brain compensates by blurring the vision of the deviated eye or ignoring it altogether (suppression). In either case there is a loss of binocularity, with a resulting loss of depth perception and distance judgment. There is no such thing as "outgrowing"
strabismus. Unless strabismus is corrected during the first few years of life, amblyopia generally results.

Amblyopia

Amblyopia (am-blee-OOH-pee-uh) is decreased visual acuity of one eye which cannot be corrected by glasses and where there is no organic disease present to cause it. Amblyopia is also defined as a significant difference between the acuities of the two eyes. It is sometimes referred to as lazy eye. The most common causes of amblyopia are strabismus and the inability to focus the eyes simultaneously.

If the image in one eye continues to be suppressed over a period of time, the brain will forget the suppressed eye. Gradually, visual acuity in this eye will diminish, and the eye will become incapable of functioning. In time the condition will become irreversible, and the eye affected with this disorder will never perform well during the remainder of the person's life.

Coordination of the eyes and their ability to work together develop from about the age of five or six weeks to
about the age of six months. The visual processing performed by the eyes and brain together is not completely fixed until about the age of six or seven years. During this interval, the eye is capable of adjusting to new mechanical alignments. This is why the earlier the wandering, lazy, or amblyopic eye is diagnosed, the easier it is to correct the condition and obtain good functional vision. Perfect binocular alignment of the eyes in all positions of gaze and good fusion of vision are the ideal objectives of correction. The longer the vision in one eye is suppressed, the more it will deviate, and the more difficult it is to correct the problem and prevent amblyopia.

**Strabismus in Adults**

Occasionally misalignment of the eyes occurs in adults who have had perfectly normal binocular vision all their lives. Suddenly, or slowly, they develop double vision, an extremely annoying condition which they have never before experienced. Since adults are not as adaptable as children, they can no longer suppress the image in one eye to avoid double vision. This condition can be treated
simply by covering or occluding one eye or the other. However, it is very important to investigate the underlying cause.

A possible cause may be a hemorrhage into the brain, where one of the nerves supplying an eye muscle originates. In this case the double vision may be the sign of a stroke. A brain tumor or other disease of the brain can affect one or more of the eye muscles, reducing or paralyzing it. If the eye disorder is the result of a minor stroke, diabetes, or high blood pressure, simply treating the underlying condition will gradually improve the alignment of the eyes and cause the diplopia to diminish. Exercises, surgery, use of eyedrops, or regular glasses usually give unsatisfactory results in these cases where there are underlying, non-ocular causes. Symptoms can be improved by placing prisms in the glasses or by occluding one eye. While amblyopia seldom occurs in older individuals—that is, the brain seldom suppresses the double image—the diplopia continues as long as the eyes are out of alignment and while both eyes are open.
TREATMENT FOR STRABISMUS

The main objectives of medical or surgical treatment for strabismus are (a) to restore binocularity by overcoming the suppression or reducing the amblyopia and (b) to obtain the best possible alignment. Treatment should be started as soon as a diagnosis is made in order to ensure binocular vision and the best possible visual acuity in both eyes. It has been shown that the overall results of treatment are favorably influenced by early alignment of the eyes, preferably by age two. Good eye alignment can still be achieved later, but good vision becomes more difficult as the child grows older. After the age of eight, amblyopia cannot be effectively treated.

Treatment should begin with a complete and accurate history. It is important to establish whether the misalignment is recent or has been present for many years. The earlier the onset of strabismus, the worse the prognosis for good binocular function. The onset may be gradual, sudden, or intermittent. A family history, perhaps including pictures, is important, since strabismus and amblyopia may be hereditary. Visual acuity should also be
evaluated, if only to compare the two eyes. A complete medical and neurological evaluation can rule out any eye disease or previous injury. Damage to one of the eye muscles or one of the cranial nerves supplying the eye can be caused by diabetes, head trauma, nerve palsy, a disease of the muscle itself, an aneurysm, or a tumor.

Nonsurgical treatment of strabismus includes correcting the amblyopia, the use of optical devices (prisms and glasses), prescribing various drugs, and eye exercises. Occlusion, when used for amblyopia, is a patching of the good eye to force the amblyopic eye to work. The use of accurately prescribed glasses, including correction for astigmatism, is the most important optical device used in the treatment of strabismus. Prisms incorporated into glasses may improve the alignment of the eyes. The use of eyedrops which change the action of the eye muscles may be helpful in very young children.

If nonsurgical treatment is not sufficiently effective, eye muscle surgery may be indicated. The surgery is based on the principle of strengthening or weakening an involved muscle. Either the end of a muscle that is attached to the
sclera is moved back or part of the muscle is removed, depending on the desired result.

MEDICATIONS THAT MAY CAUSE DOUBLE VISION

Many medications that are given for a condition affecting another part of the body have also been reported to cause double vision. These include antidepressants, antidiabetic drugs, barbiturates, cortisone-like drugs, sedatives, and tranquilizers. If you are taking any of these medications, it is important to contact a physician if you notice any changes in your vision.

SUMMARY

This lesson has described the six muscles which control the movements of the eyes. Strabismus (the misalignment of one eye) and the possible resulting diplopia or amblyopia (the decreased visual acuity of one eye) were discussed, together with possible methods of treatment.
KEY TERMS COVERED IN THIS LESSON

**Amblyopia:** Decreased visual acuity in one eye (uncorrectable with lenses) in the absence of detectable anatomic defect in the eye or visual pathways; sometimes referred to as lazy eye.

**Binocular vision:** Simultaneous use of vision in both eyes.

**Convergence:** The process of simultaneously moving both eyes inward, toward each other, usually in an effort to maintain single binocular vision as an object approaches.

**Depth perception:** The ability to perceive the relative spatial location of objects, with some being closer to the observer than others.

**Diplopia:** Seeing one object as two (double vision).

**Divergence:** The process of simultaneously moving both eyes outward, away from each other, usually in an effort to maintain single binocular vision when viewing a distant object.
**Esotropia**: A misalignment of the eyes in which one eye turns inward, toward the nose, while the other eye fixates normally.

**Exotropia**: A misalignment of the eyes in which one eye turns outward, away from the nose, while the other eye fixates normally.

**Extraocular muscles**: The six muscles located outside of the eyeball within the bony orbit that move the eyeball. They are the lateral rectus, medial rectus, superior rectus, inferior rectus, superior oblique, and inferior oblique muscles.

**Hypertropia**: Upward deviation of one eye while the other remains straight and fixates normally.

**Strabismus**: A misalignment of one eye caused by extraocular muscle imbalance, also known as tropia or squint.

**PRACTICAL APPLICATIONS**

1. Interview a parent of a child with strabismus or an adult with corrected or uncorrected strabismus. What
types of treatment or surgery have been used and with what success?

2. Cover each of your eyes separately, while looking at an object about an arm's length away. What happens to the image as you switch eyes? Does it change in size or position? If so, think about how confusing your vision would be if the brain did not fuse both images into one.

LESSON 5 ASSIGNMENT

Answer the following questions in the medium of your choice—print, braille, or cassette—and mail them to your Hadley instructor. Please be sure to include your name, address, student ID, and telephone number. If you are unsure of the answers, review the information in the lesson.

1. List the six eye muscles and tell how each moves the eye.
2. Which three cranial nerves control movements of the eyes?
3. Why is depth perception important?
4. Distinguish between convergence and divergence with respect to the eyes.

5. What is diplopia? Give two results of this condition.

6. Describe amblyopia.

7. Why is early diagnosis of strabismus important?

8. What are the goals of treatment for strabismus?