gative, such as hepatic torpor, chronic constipation, gastro-intestinal catarrh, etc. It is also recommended for children and persons of delicate taste on account of its freedom from objectional odor and bitter taste.

Edward O. Otis.

VIOFORM, iodochloroxychinoline, is an antiseptic powder recommended by Tavel, Bischler, and others as an efficient and odorless substitute for iodoform.

W. A. Bastedo.

VIRGIN HOT SPRINGS.—Washington County, Utah.

Post-Office.—Washington. Visitors accommodated in ranches near by.

These springs are located on the Rio Virgin, four miles south of Tognerville. The nearest railroad station is at Milford, Beaver County, eighty miles distant, by private conveyance. The elevation here is 3,200 feet above the sea-level. The surrounding country is of a rugged, mountainous character. According to Mr. Thomas Judd, of St. George, Washington County, the rainfall does not exceed three and one-half inches annually. The air is mild, sweet, and balmy, even during the winter months. On February 27th, 1896, the date of Mr. Judd's letter, almond and apricot trees were in full bloom in the open air. The springs are six in number, and supply a stream large enough to run a grist mill. The temperature of the water is 130° F. No analysis has yet been made. The springs have not been much improved as yet, but are resorted to by the settlers for rheumatism, skin diseases, and other affections. It is the intention of the present owners to put the springs into proper shape as a health resort as soon as the railroad has been completed to within a reasonably accessible distance.

James K. Crook.

VIRGINIA BEACH, VA. See *Old Point Comfort.*

VIRGINIA HOT SPRINGS. See *Hot Springs, Bath County, Va.*

VISCERA, HOLLOW, AND BONY SINUSES, MEASUREMENTS OF.—The formation of a standard of measurements of the hollow viscera of the human subject is attended with the difficulty that the viscera themselves vary in size, even in the same individual at different times. A cavity or tube with soft, yielding, elastic, muscular walls, allowing expansion and contraction within wide limits, must be always changing in size with the changes in its solid, liquid, or gaseous contents. There cannot, therefore, be any fixed, determinate standard; but the size must be said to be *about* thus and so, varying not only with the conditions just stated but with the development of the individual. Any consideration of dilatations due to obstruction below, or of abnormal contractions due to disease of the part itself, is outside the scope of this article; but these variations illustrate well the degree which expansion or contraction may attain.

The basis of this article is mainly the work of previous investigators, supplemented by some of my own. In determining what should be considered hollow organs there was some difficulty, since all the vascular and mucous canals might be included. I decided to limit the article to the subjects mentioned below; and, at the suggestion of the editor, I have added the maxillary sinus. For measurements of the nose, mouth, heart, and womb and its appendages, I would refer to the special articles in this Handbook, and to monographs and text-books treating of those organs. Much valuable information is obtainable from Cruveilhier, Cloquet, Quain, Allen, Holden, Mackenzie, Todd and Bowman, and Richardson.

Measurements of diameters may be understood as including the walls of the cavity or canal, which are usually so thin as practically not materially to alter what, at the best, are variable results. In some cases, as in the investigations of Mackenzie on the œsophagus, plaster-of-Paris was run into the viscus and allowed to harden. The measurements were then taken upon the mould. Whatever material is used for filling or injection, it will, of course, be necessary to support the organ in water or other fluid, to prevent misshapement; I suspect that even then the best obtainable results would be only approximately correct.

The *pharynx* is a bag-like canal, closed above but continuous below with the œsophagus, communicating in front with the nose, fauces, and larynx, and lying at the back against the first five cervical vertebræ. Its œsophageal end is usually opposite the cricoid cartilage in front and the body of the fifth cervical vertebra behind. Its length and diameters vary according as the organ is in a state of rest, or as deglutition or speech is taking place.

It is subdivided into three portions: A nasal portion, or naso-pharynx; a buccal and guttural portion, or oro-pharynx; and the laryngo-pharynx. In the modulation of the voice the oro-pharynx is the part almost exclusively affected; in deglutition, movements of both oro- and laryngo-pharynx take place.

The length is usually stated to be from 4 to 4.5 in. (10 to 11.5 cm.) which may be increased to 5.5, or even 6.5 in. (14 to 16.5 cm.), by distention, or reduced to 2.5 in. (6.5 cm.) in the greatest possible contraction. Mackenzie gives the maximum length at about 5, and Allen at 5.5 in. (12.5 to 14 cm.). Allen gives the length of the naso-pharynx at 1.5 to 2 in. (4 to 5 cm.).

The breadth varies in different parts. The superior transverse diameter, measured between the posterior margins of the internal pterygoid plates, is, according to Mackenzie, 1.6 in. (4 cm.), to Cruveilhier, 1 in. (2.5 cm.), and to Allen, 8 lines (16 mm.). This diversity of measurements shows well the great variation in size in different subjects.

The diameter of the buccal portion, taken between the posterior extremities of the alveolar borders, is, according to Cruveilhier, about 2 in. (5 cm.), but may be reduced to 1 inch by the contraction of the constrictors.

The widest part of the laryngo-pharynx, opposite the greater cornua of the hyoid bone, measures 2 in. (5 cm.). Cruveilhier, however, measuring between the summits of the greater cornua, found but 1 in. and 2 lines (3 cm.); and between the superior cornua of the thyroid cartilage, 1 in. and 2 or 3 lines (3 cm.). [A comparison of hyoid bones from different adults has given me distances, between the summits of the greater cornua, varying from $1\frac{5}{16}$ in. (33 mm.) to $1\frac{10}{16}$ in. (41 mm.)].

The narrowest part, opposite the cricoid cartilage, is about 1 in. (2.5 cm.). Cruveilhier gives the breadth in the interval between the inferior cornua of the thyroid cartilage as about 11 or 12 lines (2.5 cm.); muscular contraction here may obliterate the cavity.

The antero-posterior diameter varies less than the vertical or transverse. It is increased when the larynx is carried upward and forward, and diminished when it is carried upward and backward; it may be said to depend generally on the length of the basilar process of the occipital bone. Mackenzie gives it as $\frac{4}{5}$ in. (20 mm.) for the naso-pharynx.

The *œsophagus* varies in length according to the stature of the individual. The canal extends from opposite the fifth cervical vertebra to the level of the tenth thoracic. In the adult male it is from 9 to 11 in. (23 to 28 cm.) in length.

The diameter varies at different levels. It is narrowest at the beginning, opposite the cricoid cartilage, and becomes narrowed also somewhat in passing through the diaphragm. Allen states that it is narrowed at the beginning of the thoracic portion, being there 1 in. (2.5 cm.) in diameter. Mouton and Mackenzie made elaborate measurements, which show, among other things, that the transverse diameter is much greater than the antero-posterior. A comparison shows the transverse diameter at the beginning of the canal to be from $\frac{4}{5}$ to 1 in. (21 to 25 mm.); 6 inches below this point, $\frac{3}{4}$ to $\frac{4}{5}$ in. (18 to 21 mm.). It then steadily increases until it reaches 1 in. (25 to 27 mm.). It is from $\frac{5}{8}$ to 1 in. (16 to 25 mm.) where the tube passes through the diaphragm, and then slightly increases.

The antero-posterior diameter at its origin is $\frac{2}{5}$ to $\frac{3}{5}$ in. (10 to 14 mm.); at one-third of its length below, $\frac{1}{2}$ to $\frac{3}{4}$ in. (12 to 19 mm.); at a point two-thirds of the way down, $\frac{3}{5}$ to $\frac{4}{5}$ in. (15 to 20 mm.); at the lower end, $\frac{1}{2}$ to 1 in. (14 to 25 mm.).

The method of examination is to fill the œsophagus with plaster-of-Paris and measure the mould.

The *stomach* is very mobile and distensible, is subject to prolonged distention, and may also contract much when empty. It is much larger in those who eat but one, and that a full, meal a day. In certain diseased conditions, as in stricture of the pylorus, it may become enormously distended. In long-continued abstinence it becomes much contracted. As the result of the action of strong acids, it is said to have contracted to the size of an ordinary gall bladder.

Its length, from the cardiac cul-de-sac to the pylorus, is from 9 to 12 in. (23 to 30 cm.); Todd gives it as from 13 to 15 in. (33 to 40.5 cm.). The widest diameter is between 4 and 5 in. (10 to 12.5 cm.); at the pylorus it measures 2 in. (5 cm.), and for the whole organ 4 in. (10 cm.). The total surface is about $1\frac{1}{4}$ square foot; capacity, about 175 cub. in. or 5 pints (2.5 litres); Allen estimates the capacity as 62 ounces. The greatest circumference is 13 in. (33 cm.); the smallest, 3 in. (7.5 cm.).

The *small intestine.* It is probably impossible to measure the length of the small intestine with anything more than an approach to accuracy, because of its convoluted shape. After the mesentery is cut away preliminary to the measurements the intestine becomes lengthened immediately on manipulation, so that the length is greater than it was before the section. The calibre, too, is very variable, according to the increase and decrease of gaseous and other contents. Its length is usually stated at 20 to 25 ft. (6 to 7.5 metres).

Its calibre gradually diminishes from the beginning to its point of junction with the large intestine. Some of the older anatomists, as Cruveilhier, stated incorrectly that the intestine was funnel-shaped. Sometimes, in obstruction of the bowel, it becomes enormously dilated; and at other times may be exceedingly contracted. When distended it is cylindrical; when empty it may be elliptical.

The *duodenum* extends, in the shape of a horseshoe, from the pyloric end of the stomach to the left side of the second lumbar vertebra, opposite the superior mesenteric artery and vein. It is named from its length, which is equal to the breadth of twelve fingers. Most authors give the length as from 10 to 12 in. (25 to 30 cm.); Cruveilhier and Richardson make it 8 or 9 in. (20 to 22.5 cm.). It may be subdivided into four portions. The first, the ascending or hepatic, extends horizontally backward and to the right, and joins the second portion near the neck of the gall bladder; it is about 2 in. (5 cm.) long. The second, or vertical portion, uniting at an angle with the first, descends vertically and a little toward the left, as far as the third lumbar vertebra. Its length is from 2 to 3 in. (5 to 7.5 cm.). The third, or lower transverse portion, directly continuous with the second, is the longest and narrowest of the three; its length being from 3 to 4 in. (7.5 to 10 cm.), or, according to Todd, 5 in. (12.5 cm.). The fourth or second ascending portion ascends vertically by the left side of the spine, and is 1 in. long, (2.5 cm.).

The calibre of the small intestine is $1\frac{1}{4}$ to 2 in. (3 to 5 cm.). My own measurements in the adult have given $1\frac{1}{8}$ to $1\frac{1}{4}$ in. (28 to 31 mm.), and in the new-born infant $\frac{1}{4}$ in. (6 mm.). The circumference, as measured by Cruveilhier, was from 5 to $6\frac{1}{3}$ in. (12.5 to 16 cm.) at the beginning of the small intestine, $4\frac{1}{6}$ in. (10.5 cm.) at the middle, $3\frac{1}{2}$ in. (nearly 9 cm.) a little above the ileo-colic valve, and $4\frac{1}{2}$ in. (11.5 cm.) at the valve itself.

The *large intestine*, after removal from the cadaver, may readily be measured along its tapes. Its length is from 4 to 6 ft. (1.2 to 1.8 metre). Distention is said to diminish the length.

Its diameter gradually diminishes from its beginning to the end, except that there is a considerable dilatation just above the anus. In a general way, it may be stated to be from $1\frac{1}{2}$ to $2\frac{2}{3}$ in. (3.5 to 7 cm.).

The measurements of the individual parts are as follows:

The *cæcum* is the largest part of the large intestine (it is small in the carnivora, large in the herbivora). Its length is three or four fingers' breadth, from 2 to 4 in. (5 to 10 cm.). Its diameter is about the same as the length. Cruveilhier made two measurements of its circumference, the cæcum being moderately distended; just below the ileo-colic valve it measured 11 in. and 3 lines (28.5 cm.); in another subject, $9\frac{1}{2}$ in. (16.5 cm.).

The *vermiform appendix* varies greatly in length, being from 1 to 6 in. (2.5 to 15 cm.). Its diameter is usually given as that of a crow quill or goose quill—about one-third of an inch (8 mm.). It is a little wider at the cæcal junction.

The *ascending colon* is about 8 in. long (20 cm.); the transverse colon, 12 in. (30 cm.); the descending colon, 11 in. (27.5 cm.); and the sigmoid flexure, 22 in. (56 cm.). Cloquet states that the transverse colon is longer and larger than the ascending and descending portions, which are about equal to each other. The diameter of the ascending portion is less than that of the cæcum, and greater than that of the transverse colon. The circumferences of the parts, according to Cruveilhier, are as follows: The ascending colon and right half of the arch, 8 in. 9 lines (22 cm.) in one subject, 5 in. (12.5 cm.) in another; of the left half of the arch and descending colon, 6 in. (15 cm.) in one, and $5\frac{1}{2}$ in. (14 cm.) in the other. The sigmoid flexure was $5\frac{1}{4}$ in. (13.5 cm.) in circumference. My own measurements give a diameter of from $1\frac{5}{8}$ in. (40 mm.) to $2\frac{1}{2}$ in. (6.5 cm.) for the ascending and transverse portions and sigmoid flexure, and $\frac{3}{4}$ inch (18 mm.) for the descending portion, which, in my experience, is generally collapsed. In the infant, at term, the diameter of the colon was 1 in. (2.5 cm.).

The *rectum* is from 6 to 8 in. long (15 to 20 cm.). The first portion, from opposite the sacro-iliac joint to the middle of the sacrum, is about 3 in. (7.5 cm.) long; the second portion, to the end of the coccyx, $2\frac{1}{2}$ to 3 in. (6.5 to 7.5 cm.); the third portion, 1 to $1\frac{1}{2}$ in. (2.5 to 4 cm.). Its diameter in the upper part is the same as that of the colon, gradually increasing downward and finally contracting suddenly. Quain says that the upper part is narrower than the sigmoid flexure. According to Cruveilhier the circumference is 3 in. (7.5 cm.); in the lower part, 4 to 5 in. (10 to 12.5 cm.).

The *gall bladder* is from 3 to 4 in. long (7.5 to 10 cm.); and its diameter, at the widest part, is from 1 to $1\frac{1}{2}$ in. (2.5 to 4 cm.); in the infant, at term, $\frac{1}{2}$ in. (12 mm.). Its capacity is $\frac{1}{2}$ to $1\frac{1}{2}$ ounce (48 c.c.); it varies very much, and in some diseases may amount to 6 ounces (192 c.c.).

The *ureter* measures 12 to 18 in. (30 to 45 cm.) in length. In diameter it is equal to a crow quill or goose quill; the most contracted portion is in the substance of the bladder.

The *urinary bladder* is of a somewhat pyramidal shape; in a fairly dilated condition it measures about 5 in. by 3 in. (12.5 by 7.5 cm.); and its capacity is about 1 pint (0.5 litre), or, according to Allen, from 6 to 13 ounces (0.2 to 0.4 litre).

The female bladder is broader transversely and more capacious than the male. This may be partly due to the fact that women are more influenced by the customs of society than are men; and it is broader, also, more often in women who have borne children. The bladder is said to be relatively larger before than after birth, and relatively smaller in children than in adults. This also may be due to habit.

The temperament, nature of diet, temperature of the air, and position of the body, all may affect the size of the bladder.

The *vagina* of the unimpregnated woman averages 4 in. (10 cm.) in length on the anterior wall and 5 to 6 in. (12.5 to 15 cm.) on the posterior wall; according to Allen, the tube is $2\frac{1}{2}$ in. (6.5 cm.) long, its posterior wall being

5 lines (12 mm.) longer than the anterior. The walls may be separated in the virgin about 1 in. (2.5 cm.).

The *larynx* is said to be one-third larger in the male adult than in the female. The average length of the vocal cords is, in the male, 7 lines or ⅝ in. (14 mm.); in the female, 5 lines (10 mm.). The measurements in a number of male subjects did not vary the twelfth of an inch. In females the cords are about one-fourth shorter than in the male. The average length of the glottis is, in the male, 11 lines (23 mm.); in the female, 8 lines (16 mm.). The transverse diameter of the glottis is, in man, 3 to 4 lines (6 to 8 mm.); in woman, 2 to 3 lines (4 to 6 mm.). Mackenzie gives the diameter as ½ in. (12 mm.); in boys it is much less.

The *trachea* extends from opposite the fifth cervical vertebra to the second or third thoracic. Its length is from 4 to 5 in. (10 to 12.5 cm.), varying with the elevation and depression of the larynx and the extension and flexion of the neck. There is a difference of from 2 to 2½ in. (5 to 7.5 cm.) between full extension and extreme contraction, the contraction being limited by the contact of the rings.

Its diameter is directly related to the capacity of the lungs, and is greater in the male than in the female; it is about the same throughout its whole extent, varying according to age and individual peculiarities, and is from ¾ to 1 in. (18 to 25 mm.). In a man, aged about ninety, whose trachea I measured, it was wider in the middle (namely, 1¼ in. or 31 mm.) than above or below, where it was 1 in. (25 mm.); antero-posteriorly the upper part measured 1 in. (2.5 cm.), the lower part ¾ in. (18 mm.).

The *right bronchus* is about 1 in. long (2.5 cm.); the left, 2 in. (5 cm.). The right is much wider than the left, its diameter being nearly as great as that of the trachea itself. In one woman whose trachea I measured, the diameter was 10 lines (20 mm.); the right bronchus was 8, the left 5 lines (16 and 10 mm.).

The *maxillary sinus*, or *antrum of Highmore*, varies greatly in capacity; it is relatively small in the young and large in the old. In a number of skulls of adults I found it to vary on the two sides. From its irregular shape I made no attempt to take its diameters, but only its capacity, which I obtained by crowding raw cotton against its connecting foramina and filling the sinus with mercury. In many measurements the capacity was found to be from 10 to 12 c.c. (℥ iiss. to iij.); in a few it was as low as 8.5 c.c., and in others as high as 15 c.c. (2.7 and 3.75 drachms).

The *external auditory meatus* consists of a bony and of a cartilaginous portion. According to some authors these are nearly equal in length; others, as Allen, state that the bony portion is twice the length of the other. The entire canal is about ¾ to 1½ in. (18 to 37 mm.) in length, a little longer on the floor than on the roof, because of the oblique direction of the tympanic membrane, the anterior wall and floor extending 3 or 4 lines (6 to 8 mm.) farther inward.

The diameter varies very much. In some subjects the end of the little finger can be passed in for quite a distance; in others the canal will hardly admit a goose quill. It is not of equal diameter throughout, being narrowest about the middle, although Allen states that it is widest at the junction of the bony and cartilaginous portions. The external portion is flattened from before backward, so that the vertical diameter (nearly ½ in. or 11 mm.) is nearly double the antero-posterior (¼ in. or 6 mm.). The middle portion is more cylindrical. The internal portion is flattened from above downward, making the antero-posterior diameter (⅜ in. or 9 mm.) greater than the vertical (⅓ in. or 7 to 8 mm.).

The *tympanic cavity* communicates in front with the Eustachian tube, and behind with the mastoid cells. Its diameters are as follows: Antero-posterior, about ½ in. (12 mm.); Toynbee says, ¾ in. (18 mm.); the transverse diameter varies, in different portions, from $\frac{1}{12}$ to ½ in. (2 to 12 mm.), it is narrowest in the middle; the vertical diameter is ¼ to ½ in. (6 to 12 mm.).

The *Eustachian tube* connects the tympanum with the pharynx. It consists of an osseous and a cartilaginous portion. The osseous portion varies very much in length, according to different observers, ranging from ½ to 1 in. (12 to 25 mm.); Allen says 14 lines (about 28 mm.). The length of the cartilaginous portion is about 1 in. (25 mm.); total length of tube about 1½ in. (37 mm.); Toynbee and Cruveilhier say 2 in. (50 mm.).

The pharyngeal orifice is wide and dilatable; elliptical in shape; about ½ in. (12 mm.) in diameter. The remainder of the tube is so constricted that it barely admits an ordinary probe. Sappey gives its vertical diameters as follows: Tympanic orifice, 5 mm.; at osseo-cartilaginous junction, 3 mm.; in middle of tube, 4 to 5 mm.; at pharyngeal orifice, 6 to 8 mm. Transverse diameters: Middle of osseous portion, 3 mm.; osseo-cartilaginous junction, 1 to 2 mm.; middle of cartilaginous portion, 3 mm.; at pharyngeal orifice, 5 to 6 mm.

The *mastoid cells* vary very much in size in different individuals and at different ages, being always small in youth. In some individuals they occupy the entire interior of the bone behind the external auditory meatus for 1½ in. (37 mm.) and have a vertical diameter of 2 in. (50 mm.). They are usually subdivided, and communicate anteriorly with the tympanic cavity.

The *nasal duct*, including the lachrymal sac, is about 1 in. long (25 mm.), the sac and duct proper being nearly equal in length, namely, about ½ in. each (12 mm.). The duct proper is directed downward, backward, and a little outward; is rather ovoid in section; its diameter varies greatly and is smaller than that of the sac; it varies also on the two sides of the same individual. The upper part averages about ⅛ in. (2 to 3 mm.); the lower part is about 0.5 mm. wider. Noyes found in one case that the duct on one side was round and ⅛ in. (3 mm.) in diameter; on the other, oval, and ¼ in. (6 mm.) in diameter. The nasal terminus is somewhat dilated.

The *frontal sinuses* vary much in size in different individuals, and on the two sides of the same. They are always small in youth. The right and left are generally entirely separate, but sometimes communicate through a small opening. They are often subdivided into smaller cavities.

My own measurements of capacity gave the following results: The right, ⅓ to 1½ drachms (1⅓ to 6 c.c.); the left, ⅙ to ⅓ drachm (1⅓ to 4⅔ c.c.). As showing the difference, sometimes, between the two sides, I found in one case that the left sinus was to the right as 70 to 95. Perhaps the best idea of the size which they sometimes attain is formed from the fact that the larvæ of insects, living centipedes, musket balls, etc., have been found in these sinuses.

Daniel S. Lamb.

VISION, PHYSIOLOGY OF.—In order to read with profit a presentation of the physiology of vision one should be thoroughly conversant with the anatomy of the eye, with the general principles of refraction, and with the application of those principles to the dioptrics of the eye.

The reader is referred to the excellent articles of Dr. Baker and Dr. Gradle on the anatomy of the eye (Vol. IV., p. 63) and the dioptrics of the eye (Vol. IV., p. 83).

Vision comprises two distinct phases of activity: 1. *Optical*, in which phase the eye as an optical instrument focusses upon the retina images of objects. 2. *Sensory*, in which the sensorium is made conscious of the form and color of the image through the neuro-epithelial cells, rods and cones, and the two orders of sensory neurones.

A. Visual Optics: The Eye as an Optical Instrument.

Possessing a lens with an adjustable focal distance, a diaphragm with an adjustable aperture, a pigment lining for absorption of dispersed light, and a screen for the reception of the image, the eye must at once be recognized as a typical optical instrument. Used as it is for viewing distant objects whose image is infinitesimal compared with the object, the eye resembles a telescope. But the adjustable diaphragm in front of the lens and the screen for the reception of the image are points which make it more strongly resemble the photographic camera.

All of the optical instruments consist of two distinct mechanisms: (1) *A refractive apparatus* for focussing the rays of light, (2) *a directive apparatus* for directing the axis of the instrument at the object whose image is to be viewed.

1. Visual Refraction: The Refractive Apparatus of the Eye.—Before entering upon the consideration of this topic it might be interesting to note that the mechanical and thermal stimuli of one's environment are quite unmodified preparatory to their stimulation of the sensory end-organs, and the pressures and tensions and temperature act directly upon the sense organs transmitted practically unmodified through the superficial layers of the cuticle. The chemical agents, however, which serve to stimulate the sensory nerves of smell and taste must enter into solution before the end-organs are stimulated. Furthermore, the vibrations of ponderable matter must be condensed and intensified by the transmitting apparatus of the ear before they can sufficiently stimulate the end-organs of hearing.

Finally, the vibrations of the imponderable, luminiferous ether can only be recognized as light by the primitive eye spots of the cœlenterates and echinoderms. Nature has, through the lapse of ages, evolved a visual sense organ which is able to recognize not only the difference between light and darkness, but also to perceive the form and color of distant objects. In order to accomplish this rays of light are focussed into a clearly defined image through the refractive apparatus of the eye.

(*a*) *Application of the Laws of Refraction to the Mammalian Eye.*—See *Eye, Dioptrics of*, by Gradle, Vol. IV.

(*b*) *The Optic Disc or Blind Spot.*—(1) *The location of the blind spot* may be determined as follows (Marriotte's experiment): On a white card make a black cross and a circle about three inches apart. Closing the left eye, hold the card vertically about ten inches from the right eye so as to bring the cross to the left side of the circle. Look steadily at the cross with the right eye, when both the cross and the circle will be seen. Gradually bring the card toward the eye, keeping the axis of vision fixed upon the cross. At a certain distance the circle will disappear, *i.e.*, when its image falls upon the entrance of the optic nerve. On bringing the card nearer, the circle reappears, the cross of course being visible all the time.

(2) *The outline of the blind spot* may be determined as follows: Make a cross on the centre of a sheet of white paper and place it on the table about 30 cm. from the cornea; close the left eye and look steadily at the cross with the right eye. Wrap a penholder in white paper, leaving only the tip of the pen point projecting; dip the latter in ink, or dip the point of a white feather in ink, and keeping the head steady and the axis of vision fixed, place the pen point near the cross and gradually move it to the right until the black becomes invisible. Mark this spot. Carry the blackened point still further outward until it becomes visible again. Mark this outer limit. These two points give the outer and inner limits of the blind spot. Begin again, moving the pencil first in an upward, then in a downward direction, in each case marking where the pencil becomes invisible. If this be done in several diameters an outline of the blind spot is obtained, even little prominences showing the retinal vessels being indicated.

(3) *The size of the optic disc* may be readily determined by using the formula given below. Let x equal the long axis of the disc to be determined; a, equal the long axis of the map, as measured; d, the distance from the nodal point to the sheet of white paper upon which the map of the white disc was drawn; f, equal the distance from the nodal point to the retina: Then $x : a :: f : d$ or $x = \frac{af}{d}$.

(*c*) *Accommodation.*—See *Eye, Dioptrics of*, by Gradle, Vol. IV.

(*d*) *Imperfections of the Refractive Apparatus of the Eye.*—It will be remembered that the sole function of the eye as a refractive apparatus is to focus rays from any object, near or far, upon the retina; that when the accommodative apparatus is at rest the image of an object 6 metres or more distant is formed upon the retina in the normal eye. The distance of the image depends, then, upon the focal distance, but the principal focal distance depends in turn upon the radius of curvature, the index of refraction, and the location on the optical axis of the elements of the dioptric system. In the nature of the case the index of refraction cannot change perceptibly. In the principal imperfections of the refractive apparatus of the eye the position of the elements of the dioptric system upon the optical axis is faulty. If the screen (retina) is too far back the rays will come to a focus before reaching the retina. The subject will attempt to correct the difficulty by bringing the object near to the eye, thus increasing the conjugate focal distance until the image falls upon the retina. This bringing of the object near to the eye is a sign of a condition of the eye, which has, in consequence, been called "*near-sightedness*," or *myopia*, and it may be corrected by placing before the eyes concave or divergent lenses which enable the subject to see distant objects.

The retina may be too close to the nodal point; that is, the eyeball may be flattened in the antero-posterior diameter. In that case rays of light from a distant object would not be brought to a focus by the time they reach the retina. The subject will attempt to correct the difficulty by bringing into action the accommodative apparatus of the eye, thus bringing the focus nearer to the nodal point until it falls upon the retina and the object is clearly seen. This condition is called "*far-sightedness*" or *hypermetropia*. The oculists correct it by placing before the eyes convex or convergent lenses which enable the subject to see distant objects without the help of accommodation.

The radius of curvature of the cornea may be different in different planes. If the radius is shorter in the horizontal than in the vertical plane the rays which lie in that plane will be focussed nearer to the nodal point than will those which lie in the vertical plane. It must be evident that the eye would, under such conditions, be quite unable to focus both horizontal and vertical lines at the same time. Bringing the object nearer does not relieve the subject; using the accommodation does not help the condition. It is held by some ophthalmologists, however, that a modified accommodative act may contract the ciliary muscles in one place more than in another and thus correct or at least partially correct the condition.

The most effective way of relieving the condition without artificial means is for the subject to bring the eyelids very close together, leaving only a narrow horizontal slit. In this way all of the rays are cut out except those in one plane, and if these do not fall upon the retina when the eye is at rest, the subject may bring the object nearer to the eye or may use the accommodation. This condition of the eye is called by the oculists *astigmatism*, and it is corrected by placing before the eyes plano-convex or plano-concave cylindrical lenses which change the curvature of the refracting surface in one plane only. It is only necessary to adjust the axis of the cylinder at such an angle as to increase the curvature in the plane where it is smallest (or decrease it through the use of plano-concave cylinders in the plane where it is greatest) to put the dioptric system into approximately perfect condition.

2. Visual Mechanics.—As the telescope or the camera must be provided with a directive apparatus by means of which the direction of its optical axis may be changed, so the eye is provided with an apparatus for changing the direction of the line of vision. In directing the vision from one point or object to another the axis of the eye is turned upward or downward, outward or inward, or is circumducted, in short, the axis of the eye has an absolutely universal motion within its limits.

(*a*) *Monocular Fixation.*—The term monocular fixation is used to designate the mechanical adjustment of the eye to bring the image of the object upon the macula lutea, the most sensitive portion of the retina. If one studies the movements of one eye (the other being shaded) he will find that it readily follows the movements of an object held in front of it, however quickly or through whatever angles or directions it may be moved by the observer. The directive apparatus of the eye consists of the six muscles described in the article on anatomy, moving the eye about three different axes of rotation:

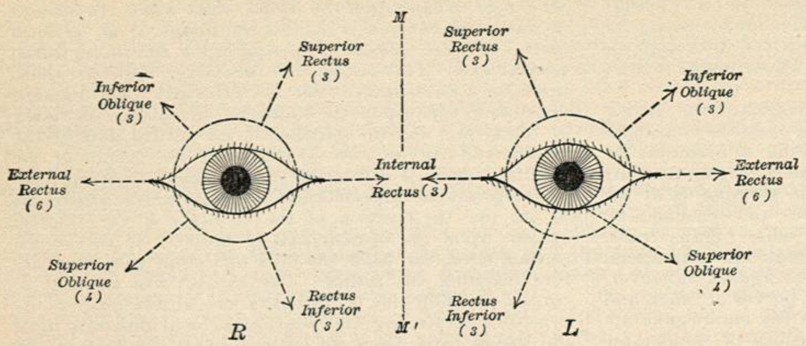

FIG. 5023.—Diagram to Illustrate the Directions toward which the Optical Axis is Directed or Inclined by the Contraction of the Individual Muscles. MM' is the median line; R, the right eye, and L the left one. The numbers in parenthesis (3, 4, and 6) indicate the innervation of the muscle. (After Waller.)

(1) A horizontal axis about which the eye rotates upward and downward; (2) a vertical axis about which the eye rotates from right to left; and (3) a longitudinal axis which coincides practically with the physiological axis or line of vision and about which the eye rotates (slightly) when the oblique muscles are in action. These three axes are rather arbitrarily located. Inasmuch as the eye is a spherical body resting in a hollow spherical socket, and inasmuch as it rotates freely in any direction about the intersection of the three assumed axes, it is somewhat simpler to take a central *point of rotation* about which the eye may rotate in any direction whatsoever under the action of one or more of its six muscles.

Waller's excellent diagram (Fig. 5023) given in the accompanying figure, will enable the student to interpret the mechanism of the directive power of the eye. Take, for example, the movement of the optical axis of the right eye outward or away from the median line in the horizontal plane. This movement is accomplished by the external rectus innervated by the sixth nerve. Again, take the movement of the axis of the eye upward in the vertical plane. It is evident that the superior rectus alone cannot accomplish this; but that that muscle must act in conjunction with the inferior oblique. In a similar manner movement vertically downward requires the combined action of the inferior rectus and the superior oblique.

In general the contraction of a single muscle causes a rotation of the eye in the direction indicated in the diagram for that muscle; while rotation in any other direction than the six which are indicated by the arrows requires the interaction of two muscles, and frequently the coördinative influence of two nerves. To circumduct the eye, sweeping its axis around a circle requires the action of all of the muscles, acting two or three at a time; an action the exactness of adjustment and the complexity of coördination of which must compel the admiration of any student of mechanics.

(*b*) *Binocular Fixation.*—This expression is used to designate the coördinated binocular movement which results in directing the physiological axes of both eyes upon the same object. If the object fixed by both eyes be a small one, its image falls upon the fovea centralis; if it be a large one, it will be disposed about that point symmetrically, as shown in Fig. 5024.

The lower part of the object being focussed upon the upper segment of the two retinæ, and the right part of the object being focussed upon the left part of the two retinæ, that is upon the median segment of the right retina and the external segment of the left retina.

It is evident that we have to deal with a complex mechanical action: (1) With double monocular fixation, and (2) with convergence of the visual axes of the eyes. If one refers to Waller's diagram he can readily tabulate the muscles involved in directing the two eyes in any particular direction. If in Fig. 5024 the object O move toward the right eye along the visual axis ONF the fixation of the right eye will not need to be readjusted. If, however, the visual axis of the left eye $ON'F'$ follow the movement of the object, it will have to deflect to the right, thus making a greater angle ($<F'Om$) with the median line (mm') than existed before. This increase of the *angle of convergence* is brought about by the internal rectus. If through weakness or through paralysis this muscle is unable to rotate the eye far enough to bring the points O, N', and F' into a straight line, then the retinal image would not fall upon the field ($a'b'c'd'$) and there would be a double visual sensation, "double vision," or *diplopia*. Failure for any other reason to produce perfect binocular fixation leads to the same derangement of vision. This is the principal, though not especially frequent imperfection of the directive or mechanical apparatus of the organ of vision, and is often corrected by oculists through the use of prismatic lenses which bend the optical axis, bringing the image upon the proper field of the retina.

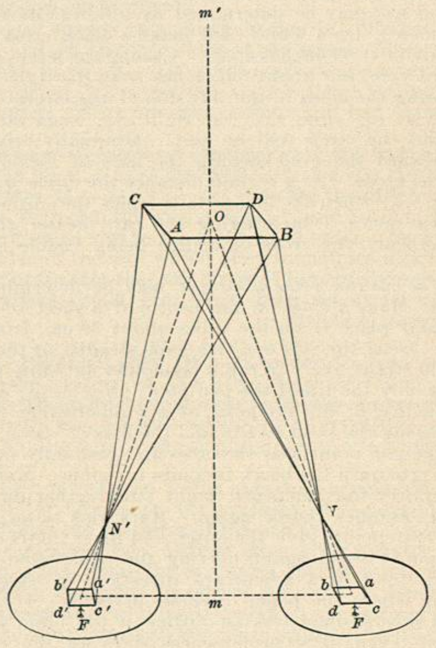

FIG. 5024.—Diagram showing the Symmetrical Correspondence of the Retinal Field. N, Nodal point; F, fovea centralis. The observer is supposed to be looking down upon the optical apparatus from above. Note that the line $C\ D$, which is on the lower side of the object, is the upper side of the image; and that the line $B\ D$, which is the right side of the object, is the left side of the image, which brings it at the inner segment of the right retina and the outer segment of the left retina.

B. Visual Sensation. The Eye as the Sense Organ of Vision.

The retina is the end-organ of vision; its function is to receive the impression of the image focussed upon its surface by the optical apparatus and to transmit the impression to the brain. About all that can be said is that the lights, shades, and colors of the retinal image excite, in the neuro-epithelial cells, metabolic changes which are influenced more or less by the action of the light upon the pigments in the associated tissues. The neuro-epithelial cells are composed of an efferent element represented by the cones or rods of the external layer of the retina that is the scene of the metabolic changes referred to above. The chemical changes start, along the afferent element (dendrite) toward the cell body, an impulse which is transmitted by the efferent element (neurite) to the first neurone of the cerebral layer of the retina, thence by the second neurone to the sensorium of the brain.

The phases of visual sensation which seem most profitable briefly to discuss are retinal stimulation, retinal irritability, and visual sensations.

I. Retinal Stimulation.—*A. The Stimuli.*—(*a*) *The kinds of stimuli* which lead to visual sensation are limited normally to: (1) Diffuse light in its various colors, and (2) images of objects. In either case the stimulus is light, but it seems expedient in view of what is to follow to differentiate between the light in general and images of objects. The retina, in common with all highly specialized tissues, responds to all stimuli with the same general sensation. If one press upon the side of the eyeball a ring of light will be seen upon the opposite segment of the retina. The retina is stimulated under the finger, but it is referred to the opposite side. When a mechanical shock to the head makes one "see stars" these luminaries are real sensations due to the mechanical stimulus. Electricity may also produce the sensation of light.

Light being a mode of undulatory motion, it may vary in two ways: (1) In the number of vibrations per unit time, (2) in the amplitude of the vibrations. The first variation is comparable to the variation in the pitch of sound and leads to the color scale; the second variation is comparable to loudness, and is recognized in the intensity of the sensation.

(*b*) *The duration of the stimulus* may be very short. An electric spark whose duration is less than a millionth of a second is long enough to produce a sensation (Waller). The sensation which a stimulus calls forth is of much longer duration than the stimulus itself. This is made evident when one looks at a rapidly rotating wheel; a spoke occupies a particular position for only an infinitesimal fraction of time, yet it calls forth a sensation. In the position which the spoke takes during the next infinitesimal unit of time another sensation is induced; but the sensation of the previous stimulus persists and the two sensations blend. The result of this blending of the images of the rotating spokes is to produce the effect of a solid wheel. In a similar way if a luminous body be attached to the rim of the rotating wheel the sensation which it produces will not be a point of light, but a more or less elongated line of light. The faster the rotation of the wheel the longer the arc of light until finally the speed of the rotation may be great enough to extend the line of light around the whole circumference of the circle in a solid ring of light. Carpentier says that an interval of 0.027 of a second must elapse between two flashes of light in order that both can be seen separately.

B. The Irritability of the Retina.—1. *Factors Involved in Retinal Irritability.*—(*a*) *The structure of the retina* bears an important relation to its irritability. The two kinds of neuro-epithelial cells—the rods and the cones—are not equally distributed over the retina. There are no rods in the macula lutea; this portion of the retina possesses the cones only. The macula lutea is especially sensitive to the fine lines of images focussed upon it; *i.e.*, it is the only portion of the retina from which one may receive a clearly defined image. That portion of the retina outside of the macula lutea is only faintly sensitive to form, but is very sensitive to light and responds to very slight modifications in the intensity of the stimulus.

(*b*) *The retinal pigments* bear some relation to the irritability of the retina. Melanin or fuscin is the brownish-black pigment which makes up the pigment layer of the retina. This pigment seems to form a stock from which other pigments may be replenished. *Rhŏdopsin*, or "*visual purple*," is found in the rods, and is therefore absent from the macula lutea. *Chrŏmophanes* are red, green, and yellow oil globules found in the cones. The chromophanes are not found in the eyes of mammals.

(*c*) *Varying irritability of different areas* of the retina is probably due to varying distribution of the rods, cones, and pigments. The following facts are important in this connection: 1. The macula lutea is the area of clearest definition of form; it is, in fact, the only area sensitive to the fine structural details of an image. 2. The macula lutea possesses cones but no rods, and in its most sensitive area—the fovea centralis—the cones are brought into special prominence by the thinning out of all the other elements. 3. The portion of the retina most sensitive to variations of the intensity of diffused light is that portion outside of the macula. 4. The portion of the retina outside of the macula is richly studded with *rods*, and each rod possesses its supply of rhodopsin. A solution of rhodopsin bleaches in the light. The retinal image may be acutally "fixed" by treating with four-per-cent. solution of potassium alum, the retina which has just been removed immediately after thorough exposure following rest in the darkness. The "fixed" image is called an *optogram*.

These facts seem to justify the conclusion that *the cones are the structures which receive form pictures, and the pigmented rods are the structures which receive light and color impressions.*

2. *Direct and Indirect Vision.*—These terms designate respectively the central field of clear definition and the surrounding field of indistinct definition. One may get a very good idea of the difference between direct and indirect vision by holding before one eye (the other being shaded) at a distance of 30 cm. a printed page. Direct the line of vision at a small word; the surrounding words will be recognized for a distance of perhaps 2 cm. in any direction, but by studying the sensation very carefully, keeping one particular letter constantly fixed in the line of vision, that one letter is the only letter upon the page that is absolutely clearly defined. The image of that letter lies upon the centre of the fovea centralis, the two adjacent letters lie upon the slanting sides of the fovea, their definition is only slightly less distinct than that of the central letter. The form of the next adjacent words can be made out with sufficient clearness to enable the observer to say definitely what the words are, but he would be quite unable to detect any slight typographical imperfection in the words. The field of direct vision may be taken to be that which is focussed upon the macula lutea which is 1.25 mm. in diameter, subtending about five degrees of angle at the nodal point.

(*a*) *Indirect Monocular Vision.* The field of indirect vision includes all of the visual field outside of that of direct vision. The accompanying figure (Fig. 5025) shows the field of indirect vision for white light bounded by the shaded portions of the figure. Note in the centre the five-degree circle of direct vision within which the form and structural features of objects are clearly defined. Note the blind spot (B) at the right of the macula in the figure, and showing that the optic nerve enters the eye to the median side of the fovea located from 12.5° to 17.5° from the centre and a little above the horizontal line from the fovea. Note that the boundary of the field for the indirect vision of the white light crosses the upper vertical meridian at 55°, the median meridian at 60°, the lower vertical meridian at 70°, and the external meridian beyond 90°. The determination of the line bounding the field of vision is called *perimetry*, the record and the instrument used in getting it a *perimeter*. The field for yellow light is within that for white, the field for blue light is within that for yellow, the field for red light still farther withdrawn from the periphery, and the field for green very much smaller than that for red. Perimetry has considerable clinical importance because in certain pathological conditions the perimeters are considerably modified either by being generally contracted or by being dotted with islands of total or partial blindness.

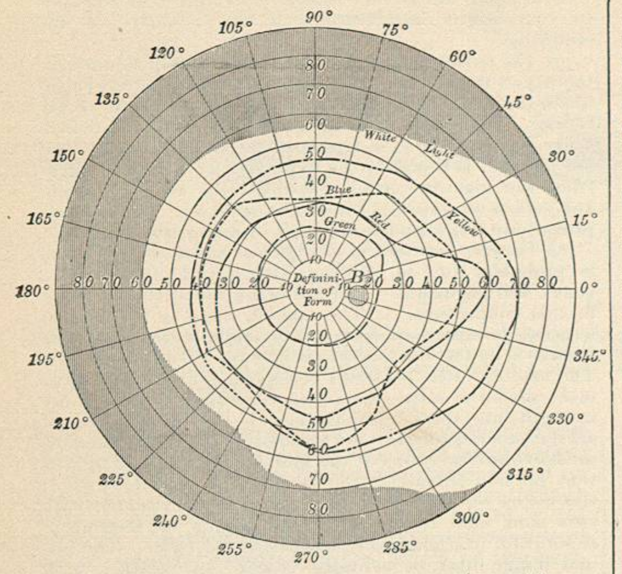

FIG. 5025.—Perimeter Chart with Tracings. (Krapart.)

(*b*) *Indirect Binocular Vision.* To determine just what the field of indirect binocular vision is one has only to find the overlapping areas of indirect monocular vision when both eyes are directed to the same point. The accompanying figure (Fig. 5025) is for the right eye. If one trace upon the same chart the field sensitive to white light in the left eye, the open external end of the field will extend off to the left and the circular median end to the right, reaching the 60° circle. The right and left perimeters will thus overlap in an almost circular area bounded right and left by the 60° circle, above by the 55° circle, and below by the 70° circle. The field thus bounded is that for binocular indirect vision for white light.

II. VISUAL SENSATIONS.—(A.) *Fundamental Sensations.*—The sensations which light induces in the sensorium may not be so easily differentiated as are those of sound, but they are closely analogous to sound. In sound we differentiate pitch, loudness, and quality, dependent respectively upon number of vibrations per unit of time, upon the amplitude of the vibrations, and upon combinations of overtones; in light we differentiate *color*, *intensity*, and *form*, dependent respectively upon number of vibrations per unit of time, upon the amplitude of the vibrations, and upon combinations of intensities (lights and shadows).

1. *Form.* The sensation of detail in structure is clearest at the fovea centralis, and decreases progressively in every direction from that point in the retina. That this specialization of form-sensation is in some way connected with the fact that of the rods and cones cones only are present in the macula, and these are brought into special prominence in the fovea, has been suggested above. But the color sensation is also induced by stimulation of the fovea, though Kühne and others show that differentiation of color is less acute at the fovea than in areas outside of it.

2. *Intensity.* Intensity depends upon the amplitude of the vibration of the medium, which last transmits the light to the eye. As in the case of intensity of sound, this may depend upon the amplitude of vibration of the sonorous or the luminiferous body, or upon the summation of the effects of several vibrating bodies. The sound produced by two sonorous bodies of the same pitch and amplitude will be more intense because of the summation of the undulations; in the same way the light produced by two candles will be more intense than that produced by one.

The sensation induced by lights of varying intensity is not commensurate with the intensity, but obeys Weber's law of sensation: "The smallest change in the magnitude of a stimulus which one can appreciate through a change in one's sensation always bears the same proportion to the whole magnitude of the stimulus" (as formulated by Foster). Applied to vision, the proportion is 1 to 100, that is, 0.1 candle power added to or subtracted from a 10 candle-power light, 1 candle added to or subtracted from a 100 candle-power light, and 10 candles in a 1,000 candle-power light can be detected, and so on.

3. *Color.* Color depends upon the number of vibrations of a luminous body, as pitch depends upon the number of vibrations of a sonorous body. The white light that comes from the sun may be readily decomposed into a number of principal colors and an innumerable number of intermediate mixtures. The principal colors have the following rate of vibration: Red, 392 trillions of vibrations per second; orange, 532 trillions; yellow, 563 trillions; green, 607 trillions; blue, 653 trillions; indigo, 676 trillions; violet, 757 trillions. These vibrations range in wave lengths from 0.00000766 mm. to about half of that length.

The colors named above are the principal or the clearly pronounced colors of the spectrum. From three of these all other colors may be produced; these three are the fundamental or *primary colors: red, green, violet.* The accompanying figure (Fig. 5026) shows graphically the relation which these colors bear to each other. Not only does a combination of all of the colors produce white, but a combination of certain of the colors in pairs produces white; these pairs are called complementary colors: (1) Red and greenish-blue; (2) yellow and indigo; (3) orange and cyan blue; (4) violet and greenish-yellow.

How the different colors can stimulate the retina has been the subject of considerable controversy.

(*a*) *The Young-Helmholtz theory* assumes that there are in the retina three different kinds of sensory elements which respond to the three different primary colors—red, green, and violet—and that "*every color of the spectrum excites all of the elements, some of them feebly, others strongly*" (Landois). The perception of color is then a resultant of the combined sensations brought to the sensorium by the three sets of elements.

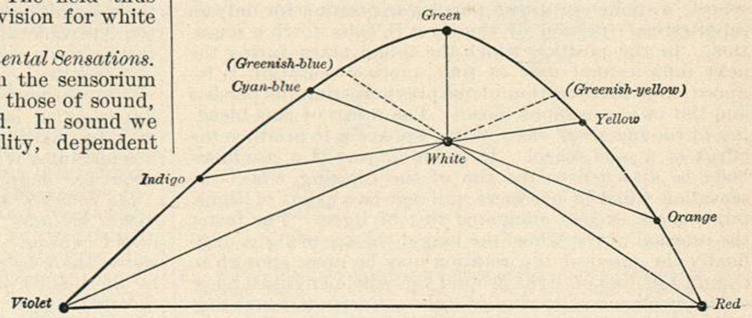

FIG. 5026.—Geometrical Color Table.

(*b*) *The Hering theory* is based upon the principles of metabolism and upon the color law of Grassman: "If two simple but non-complementary spectral colors be mixed with each other they give rise to the color sensation, which may be represented by a color lying in the spectrum between both and mixed with a certain quantity of white"; *i.e.*, every color sensation except those of the primary colors may be produced by a color of the spectrum plus white. Hering assumes: (1) That light produces metabolism in the retina; (2) that the metabolic processes are in part anabolic and in part katabolic; (3) that white, red, and yellow sensations are katabolic, *i.e.*, accompanied by disintegration and fatigue; and that black, green, and blue sensations are anabolic, *i.e.*, accompanied by integration and rest; (4) these metabolic processes are assumed to be paired—*i.e.*, white and black sensations affect the same visual substance in opposite directions. Red and green stimulate another visual substance, and yellow and blue stimulate a third. Now, according to Grassman's law of color sensation: Any color sensation, except that of a primary color, may be produced by a color of the spectrum plus white. Hering assumes that white visual substance is katabolized not only when one sees white, but incidentally in all color sensations except primary ones.

(*c*) *The Franklin theory* is not antagonistic to either of the foregoing, but rather supplementary. It is based upon the facts of comparative physiology, and assumes that the rudimentary eye distinguishes between light and dark only, and possesses neither form nor color senses; so that the fundamental point of departure is a sensation of simple light or dark (Hering's white and black sensation) produced by stimulation of a fundamental "*visual gray,*" which causes an accentuation of either the white or the black in it (presumably by modifications in the metabolism set up). This theory assumes that the yellow-blue substance was next developed and the red-green last.

The adherents of either the Young-Helmholtz or the Hering theory, especially the latter, may well accept the Franklin theory as supplementary, as it accounts easily for the fact that red-green color-blindness is most common, and yellow-blue blindness rather rare, while inability to see black and white is found only in cases of congenital, total blindness. Furthermore, reference to the perimeter chart shows that white-black covers the largest area of the retina, yellow-blue an area within that, while red-green is smallest and quite near the centre.

B. Secondary Sensations.—1. *After-images.* If one fix the gaze upon a brightly illuminated figure or pattern for fifteen seconds and then direct it toward a plain surface the image of the pattern gazed at will be seen upon the plain background of the second field of vision. If the after-image has the same colors as the first it is called a *positive after-image.* Positive after-images are usually caused by strong stimuli of short duration rather than by moderate stimuli of long duration. If the after-image is in the complementary color of the original pattern it is called a *negative after-image.* If one gaze intently at a green pattern, then turn to a red field, the pattern appears deep red upon the red field. It will also appear red upon a neutral field. *Negative after-images are a sign of retinal fatigue.*

2. *Contrast.* Contrast is the accentuation of a color sensation through contiguity or succession of another color, especially a complementary color. A piece of note paper may look white upon a black background, but if it is put upon a really white background it will be seen to be far from white. In a similar manner blue or yellow accentuate each other, as do red and green. Various other combinations have this reciprocal effect. If the effect is produced by looking at the two contrasting colors at the same time, the sensation is called *simultaneous contrast;* if by looking at the contrasting colors one after another, it is called *successive contrast.*

C. Color-blindness.—Of the male population four per cent. or five per cent., and of the female population about one per cent. are unable to differentiate certain colors. Such persons are called "color-blind."

1. *Complete Color-blindness* (*Achromatopsy*). Individuals thus afflicted can distinguish lights and shades, but have no color sense whatever. According to the Hering theory, they lack both the red-green and the yellow-blue visual substance; according to the Franklin theory they represent cases of arrested development of color sense in a condition representing a very primitive condition when only the fundamental color substance is present.

2. *Yellow-blue Blindness.* In this condition the blue end of the spectrum is absolutely dark, and the yellow may be more or less *illuminated*, but void of *color.* This represents also an arrest of development; but this arrest occurs after considerable progress has been made.

3. *Red-green Blindness.* This is by far the most common form of color-blindness, and as assumed by the Franklin theory to represent the last step in the development of the color sense and, therefore the first to fail in case of an arrest of development.

4. *Acquired Color-blindness* may result from disease of the retina.

5. *Normal Color-blindness* exists in the periphery of the retina. Passing from without inward the outermost sensation is that of white (and black); the next that of yellow and blue, followed by red and green (see *Perimetry*, on page 244).

III. VISUAL PERCEPTIONS AND JUDGMENTS.—One may have a sensation of black lines upon a white surface without perceiving in the lines a letter or word. The retino-cerebral apparatus brings to the sensorium of the untutored savage the same sensations as it does to the sensorium of the scholar. The savage "senses" a written word upon a page, but does not *perceive* it; on the other hand, the scholar may "sense" the twigs upon the forest path without perceiving in their position and condition the track of an animal. Simple sensation involves nothing higher than the sensorium. There is no reason to believe that the sensorium brings to the consciousness of different individuals different sensations. Perception involves cerebration in the interpretation of sensations. Perception involves previous knowledge or memory of the same or related sensations. Effectual perception, like effectual marksmanship, depends upon the man behind the instrument.

Visual perception is the *seeing with understanding. Visual judgments* are based upon visual perceptions and represent conclusions reached after comparison of previous perceptions.

(*a*) *Acuteness of Vision.*—It is frequently necessary to test the acuteness of vision through a comparison of visual perceptions. An individual whose acuteness of vision is in question presents himself to the ophthalmologist for examination. If the subject is schooled in interpreting dim and distorted images, he may mislead the observer for a few moments with his acute perception, but the faulty sensation must sooner or later reveal itself. The observer will present to the subject a series of letters in unusual combinations, so that there will be no way in which he can get a clew for his judgment to work upon.

To be more concrete: The acuteness of vision is tested by reading letters of various heights at various distances. The normal eye (emmetropic eye) should see clearly at 6 metres—the oculists' infinity—letters which subtend an angle of 5′; *i.e.*, letters $1\frac{1}{6}$ cm. in height. At 12 metres the normal eye should distinguish and name letters which are $2\frac{1}{3}$ cm. in height. These letters subtend an angle of 5′—the minimum angle of clear vision. If the individual can see at 6 metres what he should see at 12 metres, he is credited with: Vision $= \frac{6}{12}$; if he can see at 6 metres what he should see at 30 metres, he is credited with: Vision $= \frac{6}{30}$. If by cultivation the visual power has been brought up above the average so that he can see at 6 metres what the average eye must bring to 3 metres to see, he will be credited with: Vision $= \frac{6}{3}$.

The acuteness of vision varies much with the habits and employment of the individual. Persons employed at fine close work acquire a microscopic vision—*i.e.*, ability to see and interpret the minutest detail of structure. Persons employed in vocations which require