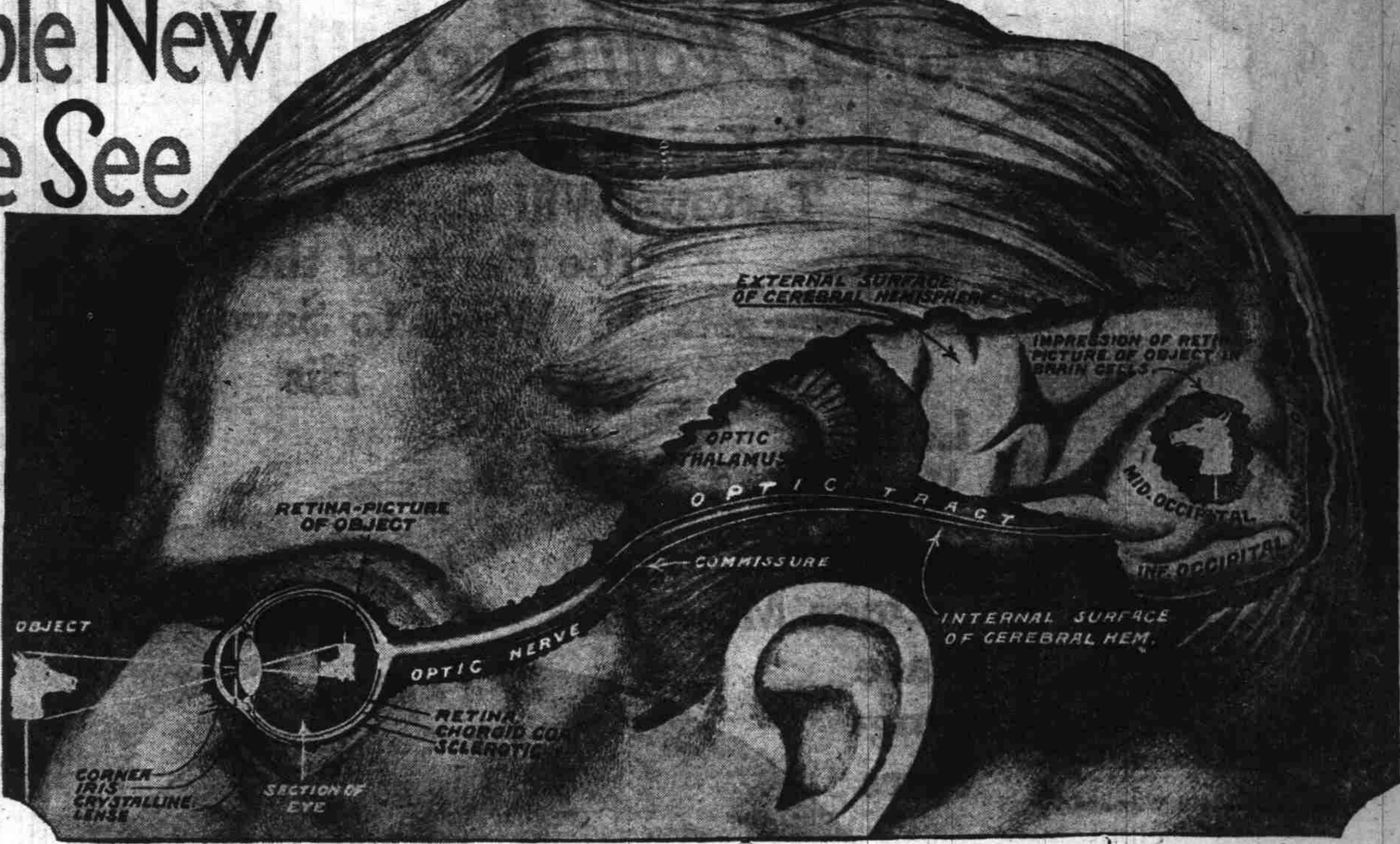
Science's Remarkable New Theory of How We See

Experiments That Seem to Show Our Visual Impressions of the World About Us Are Only a Series of Little Electric Shocks Carried Through the Eye Into the Brain



How the Outlines of an Object Before the Eye Are "Telegraphed" Into the Receiving Station in the Brain. The Rods and Cones in the Retina of the Eye Correspond, It Seems, to Selenium or Photo-Electric Cells. Thus When Different Gradations of Light Impinge Upon Them They Cause Currents of Varying Strength to Pass Along the More Than 2,000,000 Fibres Composing the Optic Nerve—Like the Wires in a Telephone Exchange—to the Proper Sight Cells in the Brain, Energizing Them and Causing Them "to See." (Diagram printed by permission of "Science and Invention," formerly "Electrical Experimenter.")

By Dr. W. H. Ballou.

ALTHOUGH the sense of sight is one that we take for granted, it is, nevertheless, in essence one of the great mysteries of life. What is it that enables us by means of the small sphere of the eyeball and the optic nerve leading from it into the brain actually to see? What is it that draws within our brains pictures of all the movements and all the colors of what is going on around us?

This mystery, in the light of the newest discoveries by science, appears to be on the verge of being solved, if, indeed, it is not already solved. Science now puts forth the theory that the sense of sight is an electrical phenomenon; that the retinas of our eyes upon which the rays of light which carry the pictures we see impinge are in reality collectors of electrical impulses, and that these impulses are carried by the wires of the optic nerve into the brain, and thereby a most cunningly arranged mechanism converted into the figures and colors which we call sight.

This theory has, curiously enough, been built up from a number of different sources of investigation working separately and independently. The English body of scientists whose experiments and conclusions are printed in the Philosophical Magazine and Journal of Science of London, Edinburgh and Dublin, were carried to their conclusions by a study of what it is that produces color vision. They found to their own satisfaction that color is the result of electrical discharges in the molecular structure of the retina set free by the impact of waves of light of varying intensities upon these structures. These electrical impulses carried on to the brain produce in the brain cells which receive them the sensations which we call red, blue, green, etc.

It has, of course, long been known that color is the result of varying wave lengths of the electro-magnetic disturbance called light. Slow waves of a certain length produce what we call red. Extremely rapid waves of short length produce what we call violet. The new point is that these waves, electrical in nature, produce their effect upon our visual organs electrically.

H. Winfield Secor, member of the American Institute of Electrical Engineers and an internationally distinguished expert upon such matters, points out in the current number of Science and Invention, formerly the Electrical Experimenter, some other surprising discoveries on the subject.

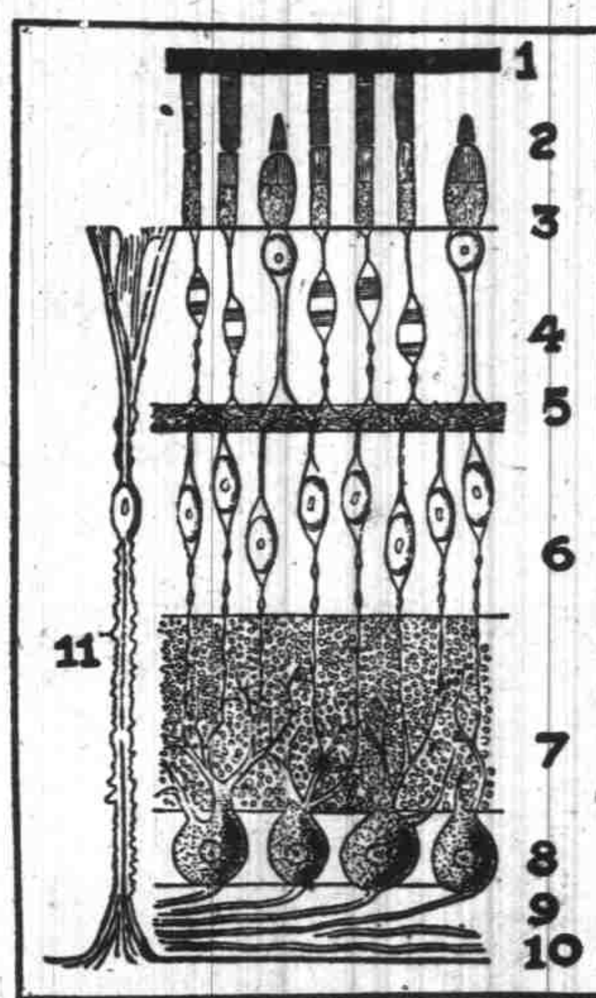
In its simplest possible terms the mechanism by which we see consists of two globes fitted with lenses through which the light waves pass to strike upon a curtain at the back of these globes which is called the retina. The retina is an extraordinarily complex structure composed of pigment cells, a layer of curiously shaped microscopically small bodies called from their shapes the rods and cones, layers of nerve cells and the filaments that connect these rods and cones with the cells.

Into the retina the optic nerve penetrates to about an eighth of an inch, presenting at this point a small rounded elevation perforated in its centre for the passage of the central artery of the retina. There are, of course, other elements in the retinal curtain, but those mentioned seem to be the only factors that are directly concerned with the reception of optical impressions—that is, they are the mechanism that is the first step toward our seeing.

The layer of rods and cones is composed of small cylinders extending through its entire thickness, closely packed and giving to the external surface the appearance of mosaic; between these is a greater or less number of flask-shaped bodies—the cones. This layer is about 1/330 of an inch in thickness at the middle of the retina, 1/400 of an inch about midway between the centre and the edge, and near the edge about 1/450 of an inch thick. The rods have a diameter of 1/1300 of an inch. They are clear, of rather a fattened lustre, soft and pliable and somewhat brittle.

It is a curious thing that shortly after death each of these rods shows under the microscope to become divided by a delicate line into an outer and an inner segment. The cones are of the same constitution as the rods and about half their length.

Upon this curtain falls the image that we see. This image we do not see upon the eye itself. It is carried back by the "wires" of the optic nerve into the centre in the brain where the image actually comes to our consciousness.



A Sectional View of the Retina of the Human Eye, Highly Magnified. 1—Macula Lutea, (Yellow Spot or Pigmentary Layer) Without Nerve Fibres; 2—Jacob's Membrane, Containing Only Long and Narrow Cones; 3—Thin Membrane; 4—Outer Nuclear Layer Containing Rods and Cones; 5—Outer Molecular Layer; 6—Inner Nuclear Nerve Layer; 7—Inner Molecular Layer; 8—Nerve Vesicles; 9 and 10—Fibrous Layer; 11—The Connecting Fibre of Muller.

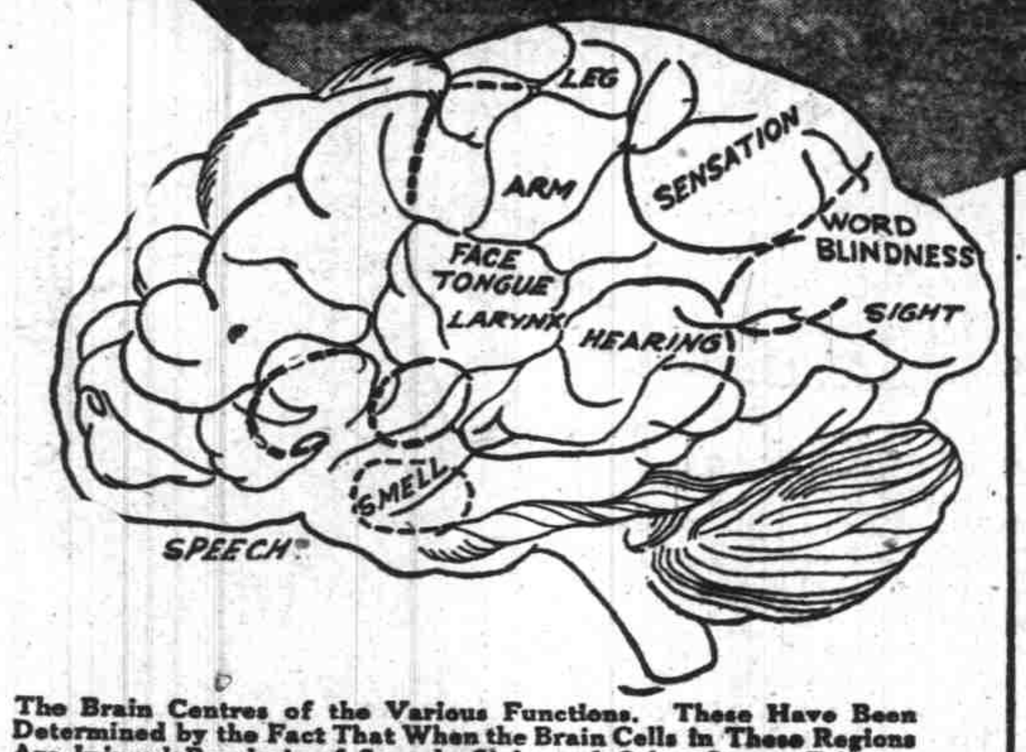
In a way of speaking, the consciousness sitting within the dark chamber of the brain looks into this mysterious group of brain cells and sees reflected there what has passed through the eye. We only think that we see with the eyes—as though they were windows in the head—which, of course, everyone knows they cannot be.

As a matter of fact, if we saw simply with the eye we would see everything upside down, because the images of things about us are reflected in that way upon the retina. Between the retina and the brain cells which receive the final electrical impulses carrying the image things are righted again in a manner which is not quite understood. As Secor points out in his article:

"The light and shade values of the image cast on the retina fall on a series of what are now supposed to be minute photo-electric cells, covering the rear inner-hemisphere of the eyeball, and there are over 2,000,000 of these cells or rods and cones, as the physiologist calls them. Each one of these light-sensitive cells connects to one of the more than 2,000,000 fibres constituting the optic nerve—the great nerve of sight, which passes up through the head to the rear of the brain or region of sight. The hundreds of thousands of optic nerve fibres, each corresponding apparently to a fine electric wire in a telephone exchange, terminate at a certain cell in the brain. Thus when we see an image, a person's face, for example, there is simultaneously stimulated in the brain a complete pattern of particular cells, which probably reconstruct the image perceived. And the result is that we do not see the object we look at upside down, but right side up!

"It is now thought that when the various points of light pass through the lens of the eye on to the rod and cone layer of the retina at the rear of the eye, extremely minute electric currents are set up and pass along the respective nerve fibres (remember, there are over 2,000,000 of them) to the cells of sight located in the brain, and it is at this point where we interpret the image or picture which the eye beholds, and not in the eye itself, as is often popularly supposed."

The Blind See with Their Hands. The Nerves of Touch Are Carrying to the Brain of This Child an Image of the Camel. The Same Cells Which Receive the Ocular Impulses Will Draw from the Touch Currents a Picture.

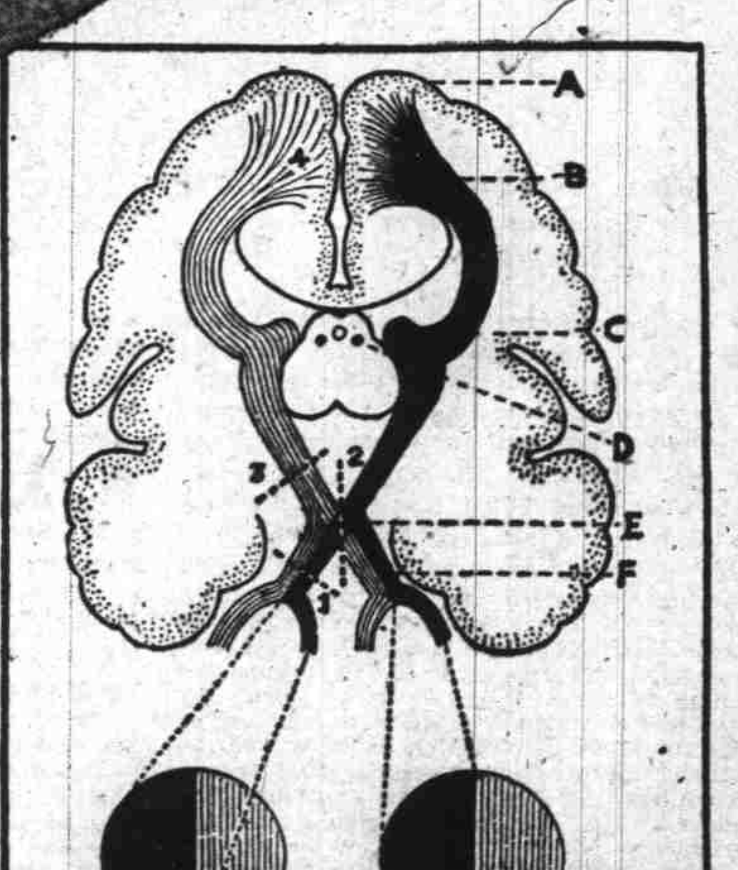


The Brain Centres of the Various Functions. These Have Been Determined by the Fact That When the Brain Cells in These Regions Are Injured Paralysis of Speech, Sight and Other Senses Follows. (Diagram from "Science and Invention.")

There is a curious metal in which, by the action of light upon it, an identical effect such as that being discussed is possible. This metal is called selenium. Its peculiarity is that the rays of light falling upon it set up within it a mild electrical current, and this current varies in intensity according to the intensity of the light that strikes it. It is possible to send photographs over wires and through great distances by means of selenium. This is done by utilizing a great number of small cells of the metal, each of which is connected by a wire to the sending cable. The image of the picture to be sent is reflected upon this mass of cells, which are arranged, approximately, like the close-packed rods and cones in the eye. Each variation of light and shadow of the reflected image sets up a varying electrical current in each cell. These currents pass over the cable to another arrangement of selenium cells, which in their turn are correspondingly stimulated, and by a certain arrangement then print the exact tones of darkness and light to which the electrical impulses correspond.

In this way a duplicate is made of the pictures at the far end of the wire.

The same principle and the same metal are used in a machine that enables the blind to read by means of the ears. A receiver composed of the selenium cells passes over the letters of the book. The different electrical impulses caused by the shadow of the shape of the letters striking the sensitive selenium cells is transformed into a characteristic sound, and as soon as the blind learns to distinguish between these sounds he is able to read.



How Sight Travels. A—Occipital Lobe; B—End "Wires" of the Optic Nerve Producing Pictures; C—Tracks of Optic Nerves, and D—Fibres Leading from Them Into the Nucleus of the Great Third Nerve; E—The Optic Chiasma or Crossing of the Nerves from the Two Eyes; F—The Optic Nerve. 1, 2 and 3 Show where Lesions of the Nerve Most Frequently Occur, Breaking the "Wires" and Causing Partial or Complete Blindness.

And regarding this, it is a fact that the blind man usually conceives different colors as sounds. Walter Holmes says:

"I once asked my brother, blind from infancy, to tell me his ideas of color, for he always asked the color of each new article he 'saw.' He told me that he got great satisfaction from knowing the color of things, but I found the realization of each color came to him as a sound. He said he knew that 'red' was a dazzling color, and that when one told him a thing was red it came to him as a shrill whistle; he knew that the foliage was green and a restful color, and when told a thing was green it came to him as soft music."

Other experiments have shown that the sensation of light can be produced in the brain centres independently of the eyes. C. E. Magnussen and H. C. Stevens, of the University of Washington, placed a solenoid or electro-magnetic cylinder over a man's head and kept him in absolute darkness.

When the electric current was turned on he reported that he saw lights. The form of the light varied with the intensity of the current.

From these experiments it has been reasoned that it may be possible to train blind men actually to see images with their brains. If the electric current can produce various forms of light in the brain it should theoretically be possible to control these forms so as to represent real objects.

That the blind possess the power of forming images in their brains of objects touched by their hands is well known. Here then we have the visual cells, cut off from actual sight, responding to the vibrations of touch and forming images in precisely the same manner as though the eyes were active. But it is a fact that the images from touch are different from those from the eyes. Professor C. F. Fraser, LL. D., a distinguished medical scientist of Nova Scotia, who is blind himself, details some interesting experiments upon this phase of the matter.

The professor experimented with eighty blind pupils and asked them to tell how many sides of a cube they could see with their minds. Those who had lost their sight at sixteen and upward visualized correctly, seeing three sides of a cube. Those who had lost their sight after reaching four years of age visualized imperfectly, seeing four or five sides of the cube at once. Those who were born blind or became blind shortly after birth lacked true visualization—thirty-three declaring that they saw six sides of the cube at once, while three of them saw but one side. This shows that in educating a blind person the instructor deals with a different mind from the normal.

Many blind persons have developed the sense of smell to an acuteness that enables them to recognize odors that are absolutely unnoticed by ordinary persons. This power is particularly developed in the deaf and blind. Laura Bridgman, the famous deaf-mute blind girl, could always recognize anybody she had met before by the smell of his hand or glove. If she met a stranger she invariably smelt his hand, and could invariably recognize him thereafter by the same means.

Blind persons who have once been able to visualize always see in their dreams.

In many cases the blind man "sees" more than one with good eyesight. The seeing man naturally sees only that side which is turned toward him. The blind man sees six sides of a box at once if he can hold it in his hand. If it is larger he may see two or three sides at once. In any case, the inspection of an intelligent blind man is more thorough than that of a seeing man who judges by appearance.

It may indeed be true that all our senses are nothing but results of different kinds of electrical impulses. The nerve current is unquestionably electric, and it has recently been pointed out by a European investigator that the nerves and nerve fibres are indeed like many electric wires, for several reasons—principally because it has been found that these parts of the human body are covered throughout with a fatty insulating covering, and, as this authority has suggested, it would seem to show that this insulated covering on the nerves and other component parts actually serves to preserve the electric potential and natural charge of the body. In certain diseases these insulations break down, causing the electric charge of the body to become markedly lowered.