Chapter 1

What is Sensation and Perception?

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What is Sensation and Perception

> A squat grey building of only thirty-four stories. Over the main entrance the words, CENTRAL LONDON HATCHERY AND CONDITIONING CENTRE, and, in a shield, the World State's motto, COMMUNITY, IDENTITY, STABILITY.
>
> The enormous room on the ground floor faced toward the north. Cold for all the summer beyond the panes, for all the tropical head of the room itself, a harsh thin light glared through the windows, …. Wintriness responded to wintriness. The overalls of the workers were white, their hands gloved with a pale corpse-coloured rubber. … Only from the yellow barrels of the microscopes did it borrow a certain rich and living substance. (Huxley, 1932, p. 1).

Thus begins Aldous Huxley's classic *Brave New World*. As an author, he is trying to both convey the setting and awaken certain associations, ideas and emotions, within you as the reader. Huxley accomplishes his goal by describing the place. This description relies heavily upon sensory information. He describes the colors, the textures, the temperature, real and apparent, of the room to convey both its appearance and to convey the sterility of the world that he will describe throughout his book that the hero will fight against. Thus, our senses provide us with this intimate contact with the world. It is the purpose of this book to illustrate to a basic degree how this miracle occurs.

This text will take a scientific approach to understanding how our sensory systems work. Like all sciences, and in fact all scholarly disciplines, the study of sensation and perception makes progress by asking questions and then systematically seeking an answer. Most texts present the answers, at least the current best answers; the information is organized around presenting the current understanding is as logical and coherent a manner as possible. As a result, the material comes a cross as a static set of facts to be memorized. In reality, the current state of affairs in science is a living body of knowledge. Each question can be asked any number of times in different ways with the result that the answer can change over time. Thus, no set of information in science is static. The ideas and the implications of the ideas change. To try to present a more living and dynamic view of science, this text will organized its material around questions. Each of the headings will be questions and the material will attempt to answer that question and indicate the basis for the answer given. In addition, a large number of dynamic media have been included in the text. In many cases, there are many more options to the media than will be discussed in the text. These options give you room to ask questions of your own and seek your own answers beyond what is covered in this text.

Do our Senses Convey Reality?

Through our senses we are presented with an incredibly rich and varied experience of the world, including the aroma of roasting coffee, the texture of fine silk, the taste of good food, the sound of our favorite musician, and the sight of a glorious sunset. Not all sensory experiences are pleasant and lovely. We have all smelled rotten milk, felt a pin prick, tasted foods we detest, heard finger nails on the blackboard, and seen images in movies that have made us close our eyes. The senses unflinchingly bring to us an immense range of experiences from the world around us. Most of our behaviors depend upon our senses: such as moving about the world, discriminating between safe and unsafe food, detecting potentially harmful situations, and understanding the communication, both language and otherwise, from people around us. Yet, for many of us, we do not spend much time thinking about how these remarkably effective sensory systems accomplish these amazing tasks and accomplish them so apparently effortlessly.

As a result, one question that you might be asking yourself is why study sensation and perception? What interesting could possibly be learned? After all, isn't it true that "Seeing is believing"? While the statement that "seeing is believing" is trite, it reveals our belief that we see, hear, taste, smell, and touch the real world just as it is. Our intuition about how our senses work is that the face of our parents, friends, and loved ones really are as they appear. We believe that our senses covey the *true* picture of the reality around us in an automatic and uninteresting fashion. Don't we just see or hear or touch? Our intuitive faith in our senses hides the fundamental question, asked in the heading, do our senses convey reality? In this book we will explore how our senses operate and I will try to convince you that the way we perceive the world is much more that what is implied in by sayings such as "seeing is believing". Not only is much more going on in our ability to perceive the world than simply making a copy of the outside world in our head, but it is far more interesting. So in some sense, the answer to this question can only be begun here. The entire text is an answer to this fundamental question.

It is important to be clear. The question asking if our senses convey reality is not the same as the question asking if our senses work. For most of us, our senses work extremely well. How well they do their job is a large contributor to our intuitive faith.

While it will be the purpose of this book to describe in detail the mechanisms behind sensation and perception, let me give you a few examples that will suggest some of the complexity of how our senses work. The quickest way to indicate that there is more to our senses than is apparent at first are **illusions [to glossary]**. You have seen and heard illusions. Illusions are incorrect perceptions. Try one here by looking at **Experiment 1.x, Müller-Lyer Illusion**. [**link to media**.]

Before describing the figure, permit me a little aside here. Sensation and perception is a very fortunate discipline. In college and almost certainly even before college, you have undoubtedly run across teachers that stress making judgments based on primary sources of information. Secondary sources, including textbooks, can often be unreliable. In science, it can be hard to present to a student the primary sources of information, the data, as that often requires equipment and materials that are difficult to bring into the classroom. However, in sensation and perception, much of the primary data is made up of the direct experience of our world. To figure out how all of this experience works, science simplifies the experience to make it easier to know what is going on. The title of this book is *Experiencing Sensation and Perception* and it was chosen carefully. It is part of the design of this text to put as many of these experiences before you as possible so that you can directly experience what is being explained. So throughout the text, instead of giving you lots of figures, you will be directed to demonstrations and even experiments. You will gain access to these demonstrations and experiments via http://psych.hanover.edu/JavaTest/Media/ESP.html … [**Need a simple description of the program: e.g.: After installing the program, you should find an icon on your desktop labeled "ESP" for *Experiencing Sensation and Perception*. Click on this icon and it will bring up your web browser to the homepage of the text. The chapters are listed along the left. To get to Media Figure 1.x, click on Chapter 1 and look for Media Figure 1.x. It also has its title, Müller-Lyer illusion. Clicking on this will bring up the demonstration.]**. It is essential that you do these demonstrations and experiments so that you will understand what is being discussed in the text really comprehend both what is believed about how the senses do their jobs and why that belief is held.

Now, back to this first demonstration shown in **Experiment 1.x, Müller-Lyer Illusion**. Do it now. When you click on the demonstration, a new window will open that fills the entire screen. There is a scroll bar along the right side of the window. You will drag the scroll bar to adjust the length of the right line, called the **comparison [to glossary]** here, until it appears the same length as the **standard [to glossary]**, which is on the left. You are trying to match the lengths of the two vertical lines. I will use the terms standard and comparison frequently in this book. The standard stimulus is always the unchanging stimulus against which you will be making comparisons. The comparison is always the stimulus that will be changed, either by you or in the experiment and compared to the standard. In this case, you will directly adjust the comparison stimulus. When you think the two vertical lines look to be the same lengths, press the button at the bottom of the window that says **They Match**. Before I explain what happens when you press this button, allow me a small explanation about one of the ways I will communicate with you in this text [**work on the phrasing here I can't find the word I want]**. Whenever I refer to an element on the program, like this **They Match** button I will change the font. I will use this **Arial Black** font which is very similar to the font you should see on your screen in the program. In this way, information about the program will be distinguished from definitions in the glossary and … [anything else I can think of that goes here].

When you press the **They Match** button the angled lines at the end of the vertical lines are removed and you will be given data that will show you the results of your match. These data will be the lengths of the two lines in pixels, or the dots that make up your computer screen. You will also be given the ratio of the length of the comparison line to the standard line. If you did a good job of the match, then the ratio should be near 1. The window that will indicate the relative lengths of the two lines may cover the main lines slightly; if you want to look at your results more directly, you can minimize or close the window with the data results. To see if the wings at the end of the lines are important to your results you can actually adjust the length of the comparison at this time while it does not have the wings. See if your ratio is closer to 1. You can start the demonstration over by pressing the **Reset** button at the bottom of the screen next to the **They Match** button.

This little experiment demonstrates the classic Müller-Lyer illusion. Simply adding lines, often called arrowheads, to the end of the vertical lines changes the apparent length of the lines. By attaching one set of the arrowheads so that they point in and the other so that they point out causes the two vertical lines to appear to be different lengths. If we see the world simply as it is, why should this be the case?

Figure 1.2. A photograph with people both close and far away. Or are they? Copyright 1999 John H. Krantz, used by permission.

The Müller-Lyer illusion and all other related illusions could be thought of as a trick. Perhaps they are not really representative of the way that our senses actually operate. Now look at the photograph in Figure 1.2. [**I am using this figure for now. I will try to construct a better option later just for the text.]** Here are four people standing on a trail. Two of the people are farther away up the trail than the other two. Let us think about this photograph for a second. The picture is flat just like paintings of scenes from the world. Yet parts of the scene appear to be more distant from you as the observer than other parts of the scene. We are used to this situation. It is part of every photograph, movie, TV show and even paintings that attempt to some extent to realistically represent depth. There are even more surprises buried in this apparently simple image. Examine **Interactive Illustration 1.x, Size Constancy** **[link to media]** which will show how information about depth plays important roles in this situation. In this figure, two of the people remain and all looks normal. The trail has been replaced by a grid pattern that helps to suggest depth in the picture the way that the trail had done. On the right of the image there are three checkboxes labeled **Texture Gradient [to glossary]**, **Relative Height [to glossary]**, **Relative Size [to glossary]**. They are checked when you start the image. These are depth cues (see Chapter 8) that help create the appearance of the depth in the image. When you click on the words next to the check boxes to remove the depth cue, you will have the opportunity to compare the sizes of the two people in the image without that depth cue. First, click on the depth cue **Relative Size** to remove it from the image. Now the two people are objectively the same size. Measure them if you like to confirm this fact. Do they appear that way to you now? Most people will respond that the figure that appears closer appears to be smaller now. Both images are both the same size and the same distance from you, but they do not appear to be either. Play with the figure, adding and removing the depth cues in any combination you like. Here is a chance to ask some questions. What is needed to make the farther person look small or normal sized?

Now try an example of an illusion from audition. Listen to **Interactive Illustration 1.x,** [**Direct to Shepherd Tones demonstration – if cannot make, get from Audio CD – see if there is a way to make it interactive]**. Listen carefully; the tones are played in pairs. The second tone always sound higher than the previous tone and in the next pair of tones, the first tone is identical to the second tone of the previous pair. Yet, eventually, the sequence is at the same place as at the beginning. How is this possible?

This sequence is call Shepherd Tones after Roger Shepherd (1964), the psychologist who developed the sequence based on his theory about how we hear musical relationships.

Now for an illusion from touch. You will need to do this one yourself. Get a friend to help you. Cross your first two fingers and close your eyes. Now have your friend place the pencil carefully between the two crossed fingers. How many pencils do you feel? Many people experience the sensation of two pencils even though only one is present. This illusion of touch is called Aristotle's illusion.

If we simply see the world as it is, why do we experience these illusions? Do they mean we don't see the world as it is? Well, that is a difficult question. First let me answer a different question. Do our senses work? YES! You have evidence of that fact every day. You don't run into walls. You are able to understand and respond to what other people say, etc. As was noted at the beginning of this chapter, our senses give us an incredibly rich experience of the world and this experience is very important us in many different ways. However, the question of what the world actually consists of is a complex question and more the topic of physics than psychology. Let us stick with psychology. What these illusions do tell us is that we don't simply make a copy of the outside world in our head. Something much more interesting must be going on, or these illusions would not occur so often and be so much a part of our life. So there are many very interesting questions about how we accomplish sensation and perception. How we know that the world is there and what is going on is an interesting and complex process that is worth our investigation. We will even see evidence that sensation and perception are active processes; that is, we participate to some extent in how we perceive the world.

Why is Sensation and Perception a Part of Psychology?

To answer this question, some terms need to be defined. Definitions can be tricky. The given definitions are used to ease communication. The terms that need to be defined and distinguished are **sensation [to glossary]** and **perception [to glossary]**. Sensation is often considered to involve all those processes that are necessary for the basic detection that something exists in the world. For example, a sensory process might be detecting the loudness of a sound or the type of taste in a food. Perception identifies and interprets this sensory information. So the sound becomes a cat's purr and the food becomes a perfectly prepared steak. Sensation is very basic, and perception involves certain aspects of our cognition. There is often a chapter on perception in basic cognitive psychology textbooks (e.g., Galotti, 2001, Solso, 2001). While this distinction is useful and will be used in this book, it is important to remember that the processes of sensation and perception are very integrated and it is often hard to distinguish a sensation from a perception.

Now, on to the question, why is sensation and perception a part of psychology. Often I suspect that this question implies that this course belongs more in biology than psychology before they take the course. There are several ways that an answer to this question can be approached. First, let us examine the definition for psychology and then, second, a demonstration of perception.

Think a minute about the definition you should have learned in introductory psychology. It probably was something similar to this: "Psychology is the science of behavior and mental processes." (Davis & Palladino, 2000). Psychology seeks to use the scientific method to understand all aspects of behavior and mental processes. Sensation and perception is certainly a mental process.

At a deeper level, sensation and perception plays a role in many other mental activities and even in our behaviors. The world we experience is defined by what our senses can pick up. There are many features of the world that play no role in our behavior because we do not sense them. In our technological society many types of radiation pass through us all of the time, but we are oblivious to them. They are irrelevant to our experience of the world; for example, FM band radio waves. Humans are completely unaware of them and yet they are all around. Compare us to a radio. The radio does have a sensory organ of a sort that can perceive these radio waves. We call this sensory organ on a radio an antenna. The antenna of a radio receives the radio waves that are in its immediate area – all of them. The tuner in the radio selects out the particular band of radio waves. The information in those waves is converted into a format we can detect: sound waves. While we can perceive the sound waves, the radio waves are just as real but they form no part of our experience of the world. Thus, the world we experience is determined by the nature of our sensory systems.

This fact has important implications for how we study the world around us. Take, for example, the work of Sir Isaac Newton (MacAdams, 1975). Newton is certainly one of the great physicists of all time, but he is also an important figure in the history of psychology. Parts of Newton's *Optiks* (1730/1952) are in as many ways a psychological study as it is a study of physics. In his studies with prisms, he thought that he was seeing effects of spreading the constituent elements of light and of recombining them.

However, the wavelengths do not really separate and recombine as you pass them through two prisms (Figure 1.5). We now know that the prisms were spreading the wavelengths due to the different amount of bending that each wavelength goes through as it passes through the glass of the prism (see Chapter 3). The wavelengths simply spread apart and come closer together. The same wavelengths are present the entire time. Wavelengths do not mix or change their nature in any way depending on how close or far apart they are. Colors, on the other hand, do mix or separate depending on how far apart they are. The rainbow appears very different from white light. White light does not seem to be a mixture of anything at all. The mixing of colors is not part of the physical world but is a property of how we perceive light (see Chapter 6). When Newton was studying the separation of white light into the rainbow and then the recombination of this rainbow into white light, he was experiencing and describing a fundamentally psychological process.

The important point here is that before there were independent sensors that physicists and the other scientists could use to measure the events in nature, their findings were often a complex combination of both natural events and the operation of sensation and perception. Therefore, in this text we will have recourse to researchers in other disciplines because their work has a psychological component to them.

Now let us take a different tack on this problem. So far the illustrations have assumed that what we perceive is dependent solely upon the nature of the stimulation coming in from the outside world. However, it is often the case that what we expect or think or what is around the stimulus can alter how we perceive an object. Remember that perception refers to our identification and interpretation of a figure. Try two examples.

First, examine **Interactive Illustration 1.x, What is this Figure?** [**link to media]** to see how the context for what our senses experience will influence what we actually perceive. Look at the figure in the middle of the illustration. What is it? A "13" or a "B"? Click on the word **Next** that is below the figure. Now does it not look like a **B** written in a font style such that there are some gaps in the letter? Click on the next button again. Does it look now like a **13**? Clicking on the button a third time will combine the two preceding images so that you can see all of the contexts at once. Continued clicking on the "next" button will cycle through all possible combinations again and again. This is a classic demonstration of what is called top-down perception (Robertson, 1998). The stimulus itself does not change, but your interpretation of it does. You see it differently depending on what surrounds the stimulus. You will see more of these types of figures in Chapters 5 and 15. They give important information about our sensory systems. What we see, hear, taste, etc. is not simply the result of what happens in the world; it also depends upon basic psychological processes that take into account what we expect to see, hear, taste, etc. In this example, your expectations of what you saw was set to some extent determined by the other figures around the central figure (the 12 and 14 or A and C).

The last example showed how the context in which we see something can alter how we perceive an object. This next example will show the active influence of our mental activities on our perceptions. Look at Figure 1.7**[Turn this into a media figure?]**. This is a classic image that can be seen one of two ways (we will see more of these in Chapter 5). You can either see a vase in the middle of the figure or two faces looking at each other along the side of the figure. The stimulus in no way changes when you see one or the other interpretation. Nor does the context change. You control what you see. You are flipping back and forth between the two interpretations. Here psychological processes constrained by our cognitive and perceptual limitations, select one of two possible ways to see this image. This act is fundamentally psychological.

As a final tack on the issue of sensation and perception and psychology, recall the passage from *Brave New World*. Consider the emotions and associations conveyed by the sensory experiences described in that room. As can be seen in that brief description, our sensory experiences can have profound impacts on us. If we are to understand psychology completely, we need to understand this topic.

I hope that in these several examples that you can see the fundamental role that sensation and perception plays in psychology and that psychology plays in sensation and perception. Psychology and sensation and perception are fundamentally intertwined with each other as I will illustrate throughout the text.

If Senses do not Convey Reality, What do our Senses do?

Given all of the examples that I have used so far, I hope that you are beginning to appreciate that our sensory systems do not simple provide a copy of the world for our heads. Our sight is not a complex videotape machine; our hearing is not a complex tape recorder; our touch smell, and taste senses do not simply copy those sensory experiences into our brains. The illusions, and in an even more fundamental way, the connection of our experience with other aspects of psychology such as cognition imply that what our senses do is something different than act like sophisticated recording devices. However, just because we don't get a copy of the world in our head, does not mean that our senses are not useful. On the contrary, useful is exactly the word to describe our sensory systems. You don't run into walls, you hear when your name is called, you can find your keys in your pocket or purse, and you enjoy a good dinner. All of these experiences indicate how useful these senses are. To place the idea that our senses are practical, it is necessary to examine how, from a biological standpoint, positive features come about. This discussion will place humanity and our sensory systems in the context of all of the animals on the earth and their sensory systems.

[I NEED AN IDEA FOR A GRAPHIC OR INTERACTIVITY HERE]

The Concept of Natural Selection

Darwin did not propose The Theory of Evolution. In Darwin's time there were several theories of evolution. What Darwin proposed was a unique mechanism for evolution. Darwin proposed the theory that evolution is driven by **natural selection [into glossary]** (Eiseley, 1958). Often natural selection is discussed as "survival of the fittest". The idea is that those characteristics that help an organism survive and reproduce will be more likely to be passed on to the next generation. As the generations pass, these beneficial characteristics will spread through the population. So, in a very crude sense, the ability to see, hear, touch, smell, and taste, all have help our biological ancestors survive and that is why we have these senses. Thus, we can ask what purpose does each of our senses serve. If they provided our ancestors with an advantage, what advantage was it?

However, this description of Darwin's theory of evolution is actually incomplete. For natural selection to work, there has to be something to select. Thus there has to be variation within a species if some are to have some competitive advantage for survival and reproduction. Variation has several sources.

First, there are mutations. Mutations are random changes in genes that result from a number of different processes. Most mutations are harmful and many are often fatal. Occasionally, some mutations produce changes that benefit the individual. These modifications can spread throughout the population.

Second, for most animals and plants there is sexual reproduction, or reproduction by the recombination of chromosomes where there are different genders. In sexual reproduction, there are two copies of each chromosome. Each copy of a chromosome has the same genes. In the most basic situation, only one of those genes is expressed or operates to produce the proteins that eventually determine our characteristics. The idea of having only one of a pair of genes expressed does not make a lot of sense if both genes are the same in every case. It makes more sense to suppress the expression of one gene if the two genes differ so that only one of the variations indicated by the genes is ultimately a part of the person. So within a species there is often more than one type of each gene. For a simple example, consider the basic inheritance for eye color. There are genes that lead to brown eyes and others that lead to blue eyes. Sexual reproduction serves to mix these genes up, increasing and spreading around this variation.

In fact, variation itself can be important to the survival of a species. The example of the moths in England during the industrial revolution is a clear example. Most moths before the industrial revolution were light colored but there were some that were darker. The light colored moths had an advantage because the trees were light colored and they were harder to spot. However, in the industrial areas the trees were darkened and the darker moths had the advantage. In these areas, the proportion of the dark moths increased. If there had not been dark moths present, the moths as a species might have been much more seriously threatened by the change in the environment caused by the industrial revolution.

Thus, even when one gene gives an organism advantage, it is often not the case that it becomes the only possible gene of that type in the species. The competitive advantage may be relative, so there are often multiple versions of every gene in a species. Having multiple copies of a gene can help a species adapt to change in the environment.

To summarize, within the theory of evolution there are forces that lead to variations with a species, mutations and sexual reproduction; and a force that leads to a reduction in variation, natural selection. However, since natural selection is based on events in the environment, the presence of predators, weather and the like, this means that those characteristics that are selected are preferred because they work well in the species' environment. As a result, natural selection serves to help an animal work well in its environment. There is a match between the demands of the environment and the characteristics of the animal. The match is not perfect but good enough for the species to survive.

[I NEED AN IDEA FOR A GRAPHIC OR AN INTERACTIVITY HERE]

The Role of Natural Selection in Our Senses

It seems reasonable to ask what evolution and natural selection have to do with our senses. However, all features of our make-up, including sensory systems, are a product of natural selection. This fact has a lot of implications for the nature of our perceptual experiences. It affects both the questions we ask and what we ought to expect of the way our senses work.

First, because of the fact that the senses are evolved, we should not expect, as indicated by the illustrations above, that they work because they recreate a perfect model of the world in our head. The senses only have to function in a way that creates a working model, not a perfect one. In fact, as long as the way our senses work allows us to function in the world and to survive, there is no need for them to create an experience that in any way resembles the actual physical world. It must correspond to the physical world in a meaningful way so that we can function, but it does not need to resemble the physical world itself. Nor does the correspondence need to be direct or exact, as we saw in the illusions above and will see throughout the book.

As a corollary to this point, we should not expect every animal's senses to create the same model of the world. In other words, your pet does not perceive the world in the same way as you do. Since our senses work to server our needs in the environment in which we evolved, other animals should have senses that work to fit their needs in their environments. We share much genetic material with other mammals, and we even share some features of the environment, so even though we might expect some similarity between our sensory systems, the other mammals do have different environmental needs and, as a result, will develop different specific adaptations in their senses. Thus, while we can learn about our own sensory systems from looking at animals, we need to be aware of differences. Through this book there will be frequent use of animal data to help us understand how human sensory systems work. In addition, I will try to highlight some interesting differences between some species through which we can see the result of natural section matching our sensory abilities to our needs.

Second, because our senses provided our ancestors an advantage in survival and reproduction, then we can ask why our senses work the way they do. Thus evolution allows us to ask teleological questions. **Teleology [to glossary]** refers to asking questions of function and purpose behind why animals have some certain characteristic. Not content to simply know that smell led to our ancestors surviving better, we can ask more specifically in what ways smell enables us to survive better.

Third, since variation is a key feature of natural selection, we should not expect that every individual in a species should have exactly the same sensory system. There should be some variation across a population of individuals. One example is what is commonly called color blindness (Chapter 6). Those we describe as color blind are not literally color blind, but they possess a different type of color vision. They lack genes or have different genes and thus see colors differently than the majority of the population. Since most of us have what can be called "normal" color vision, there must be some advantage to having our type of color vision. However, there may be some advantages to the alternative types of color vision or it might not occur at all in the environment (see Chapter 6).

A Historical Perspective

To fully understand any discipline, it is often helpful to understand some of its history. Often the questions asked in the past and the way they were posed influences modern research. It can also help us to understand our own assumptions about the nature of the world by seeing the ideas from different epochs when the ideas are very different. Sometimes a field does not even make sense until its history is considered. I feel that psychology falls into that group given the incredibly wide range of questions that it addresses. In this section, a very simple history of the field of sensation and perception will be covered to give some context to the material in this chapter.

The Beginnings

In some sense, the study of the senses dates back to very ancient times. Certainly Aristotle did some early conceptual work and observations in the field of sensation and perception. He clearly distinguished between sensory and motor functions; he described the sensory organs and their functions; he even gave us our prototypical list of five senses: sight, hearing, smell, taste, and touch (Murphy & Kovach, 1972). In addition to these basic ideas, Aristotle was a keen observer and is the first to record two very interesting sensory phenomena.

The first is an illusion of touch that still bears his name, the Aristotle illusion (Benedetti, 1985). In this illusion, a single touch between the tips of two crossed fingers, say with a pen, will be experiences at if there were two touches, as if it were two pens and not a single one. It will be discussed further in Chapter 12. The second is the motion aftereffect (**Interactive Illustration 1.x, Motion Aftereffect**. **link to**

media). An **aftereffect (to glossary)** is a sensory experience that occurs after prolonged sensory exposure. In this demonstration, you will observe a moving figure and after watching this motion examine a still figure and see if it still looks as it ought. In **Interactive Illustration 1.x, Motion Aftereffect**, the illusion that Aristotle mentions is illustrated. Press start and watch the lines move. After a while they will automatically stop. The question is whether the bars or any thing else you might view appear still now that they are. This illusion will be discussed more in Chapter 7. Aristotle obviously did not have a computer display to produce this illusion; he observed it at a waterfall (Verstraten, 1996; Wade, 1996). As a side note, it seems that Aristotle did not record the direction of the aftereffect. That honor apparently falls to the Roman philosopher Lucretius (Verstraten, 1996).

Aristotle also made some claims that we find rather odd from the perspective of the early 21st century. For example, he developed the emanations theory for vision (NEED REF). He claimed that the eye sent out emanations and picked up images of object that then returned to the brain to be perceived.

Without spending too much time on Aristotle, there is an important point to made about what Aristotle believed about vision. Careful observation and even the discovery of important phenomena do not always require experiments; take Aristotle's discovery of the Aristotle illusion and the motion aftereffect. Let us look at another example from a slightly earlier period of history to show that the role of careful observation outside of what we think of as formal science can lead to very useful knowledge.

The Greeks of the 5th century BCE had identified many visual illusions (Dinsmoor, 1950). This is evident in how at the height of the classical period they built the Parthenon. Doric architecture is subject to many visual illusions (Figure 1.x). The cornice is triangular shaped and the bottom tends to appear to bend down. The columns are tapered and tend to appear to lean out if they are vertical (Coren & Girgus, 1978; Dinsmoor, 1950). Try **Interactive Experiment 1.x, Column Taper Illusion [NOT DONE]** to see a demonstration of this latter illusion. Click on the arrow that will tilt the outer columns in a mirror image to each other. Click the columns so that they are both parallel to the central column and vertical. When they are vertical for you, click on the **Vertical** button and the columns will no longer be tapered and you can see if you lined them up vertically. [**work on how this might best be done]**. The Parthenon is an amazing structure that is built to compensate for these illusions so that the Parthenon appears to be very regular when it is anything but.

The other point to be learned from Aristotle's beliefs is that without careful examination of a lot of data and clear scientific methods, our ideas can be wildly off the mark. Science in particular gives us tools to carefully check our beliefs, which helps keep them from getting wildly off the mark. His emanation theory does not make sense to us now. Through careful experimentation we have learned that light bounces off objects and enters the eye, not the other way around. A simple experiment that Aristotle could have done would have been in a dark room to block or open a light source like a candle and see what happened to his ability to see a surface. The emanations from the eye would be the same, but the light from the candle would be different so he could easily see that an emanation explanation would not be very tenable. Observation is important, experiments make those observations far more powerful.

Many philosophers and scientists prior to the 19th century have developed ideas about perceptions, some of which still impact our thinking today. For example, the astronomer Robert Hooke developed the first acuity test in the 18th century (Grüsser, 1993). However, it is with the 19th century that we see the beginnings of a real science of sensation and perception. Before the beginnings of psychology, the contributions came from people in many different disciplines. Biologist Johannes Mueller (1840/1943) developed the **doctrine of the specific nerve energies [glossary]**. During the first half of the 19th century, the electrical features of the nervous system were being uncovered. One of the confusing findings of the time was how similar the electrical activity was in all of the neurons. This lead them to wonder how the brain could distinguish between seeing an apple and hearing a song, for example. The doctrine of specific nerve energies, in brief, argues that it is the specific neurons activated that determines the particular type of experience. Those neurons involved in seeing will cause the impression of seeing regardless of how they are stimulated. So if a sound stimulates neurons involved in vision, then you will still have a visual experience.

Mueller's work was greatly extended and built upon by the research of his student, Hermann von Helmholtz (Cahan, 1994). Helmholtz was principally a physicist (Wade, 1994). His work in that science is monumental: where, among other accomplishments, he helped formulate the law of the conservation of energy. In biology, Helmholtz was the first person to time the speed of the action potential. In psychology, Helmholtz wrote a comprehensive three-volume treatise on vision, *Physiological Optics* (Helmholtz, 1924, 1925a, 1925b), and a major work on hearing. It is his work on vision that has had the greatest impact today. He developed the concept of the trichromatic theory of color vision far beyond the earlier work of the philosopher Thomas Young (discussed in Chapter 6), which is still influential. Helmholtz also developed one of the major influential general theories of how it is our senses work. It could roughly be called a "**constructivist theory" [to glossary]** or approach. Helmholtz argued that the information from our sensory systems is inadequate to explain the richness of our experiences. Recognizing the face or voice of a loved one is more than simply the basic sensations. We must incorporate, to use modern phrasing, information from our cognitive processes to complete perceive the world around us. This involved sensory information being processed in what Helmholtz called the **unconscious inference [to glossary]** (Turner, 1977). In other words, our senses do not produce sufficient information about the world so we must use a form of reason, unconsciously, to make an educated guess about what we actually perceive. This type of theory is useful for explaining the occurrences of the illusions such as were illustrated at the beginning of this chapter. In those instances, the inferences were wrong.

As Mueller and Helmholtz were doing their research with a heavy physiological emphasis, science with a more psychological feeling was coming into being. Work by E. H. Weber established one of the first laws of psychology. Weber identified an interesting relationship describing our ability to tell that two stimuli are just different. Take how loud a sound is. When a sound is very weak, we can tell that another sound is louder even if it is barely louder. When a sound is very loud, to tell that another sound is even louder, it has to be much louder. Weber was able to develop an equation that summarized his findings, called Weber's Law, that is still referred to today. (See Chapter 2)(Marshall, 1990). Gustav Fechner was curious about the relationship between mental events and the physical stimuli in the world around us. From these considerations, Fechner developed the discipline called **psychophysics [to glossary]**. The publication of his book, *Elements of Psychophysics*, is often considered the beginning of the psychological study of sensation and perception (Fechner, 1860/1966). In this book, Fechner outlines the methods that allow the measurement of the relationship between a sensation and a person's response to that sensation. In Chapter 2, you will become familiar with these methods, which form the bedrock of many of the key studies of sensation and perception up to today. One of the features of Fechner's work was an attempt to extend the Weber's Law to explain a wider range of sensory phenomena. His research was not done in isolation but fit the spirit of the time. There were many people interested in the best way to describe the relationship between how strong a stimulus is and how strong our experience of that stimulus is. Let me give a very simplified example; if I put a 5 pound weight in your hand and then put a second 5 pound weight in your hand, will the weight in your hand now feel twice as heavy as it did before? It would be great if it did, but it usually will not. The research was directed to finding a simple mathematical description that would explain how our perception of the weight increase relates to actual weight increase. More than that, researchers hoped to find one description that would relate to any sensory dimension, such as brightness, and not just one like the perception of weight. This question has many important applications which were driving this effort. One of the first attempts to make this type of general sensory law was done in the 18th century by Mayer, an applied mathematician and astronomer who wanted the law to help correct the effects of human response time on astronomical observations (Grüsser, 1993). In addition, another 19th century scientist, Delboeuf, also, developed a law relating stimulation to our responses similar to that of Fechner (Nicolas, Murray, & Farahmand, 1997). Even Ewald Hering, better known to psychology for his color theory, developed a competing law relating stimuli to our responses (Grüsser, 1993). Fechner's law, the most famous of these laws, will be described in Chapter 2.

The 20th Century

The 20th century saw rapid development of concepts and ideas in sensation and perception. In addition, the topics of the field became increasingly varied. As a result, it is not possible to do justice to all of the major developments of the past century, so I will simply hit a few highlights. In particular, I will discuss the development of ideas or theories about how sensation and perception occur, the dramatic impact on the field by the development of physiological methods that threatens to engulf the discipline, and how sensation and perception has been applied in the world around us.

Philosophical Positions. The theoretical basis of our understanding of perception developed rapidly in the 20th century. One of the most important theories that came out in the early part of the century and was in direct contrast to the position of Helmholtz was that of **Gestalt psychology [to glossary]**. Let us examine the experiment that played a key role in the founding of the Gestalt psychology. While Gestalt psychology became a general theory of psychology, a perception study is at the foundation of the theory and clearly illustrates the heart of this theory (Schultz & Schultz, 1992). So bring up and start **Interactive**

Illustration 1.x, Phi Phenomenon **[link to media]** to see what excited the Gestalt psychologists. When the window for the media figure comes up, you will see a button that says **Across Screen** at the top and a slider at the bottom and two red circles blinking on and of about the middle of the screen. Now it should be clear that the two circles flickering on and off are still. You will probably be able to see each circle go off and if you look between the two circles you will not see anything. The circles only appear at the two static locations. Yet, many people report some impression of motion between the squares, but not that the squares are moving. This is not the apparent motion that is observed in movies and television, which are also made of a series of static images. In movies or television, the objects really appear to move just in the same way as real objects do. Let us play with the slider at the bottom of the screen to try to make the issue clearer. The slider controls how long the screen is dark between the times when the two circles are on. If you move the slider to the left, the dark time between the two circles gets shorter; and when you move the slider to the right the dark time gets longer. First move the slider to the right. Eventually, you will find a point where the two dots seem to turn on successively. There is absolutely no impression of motion. Now move the slider to the extreme left. Now, depending on your monitor speed, you should get the appearance of the dot actually moving from place to place. You will not see the dark interval between the two dots and the dot will appear, during the motion, in the places between the two still places. These are the same dots as before and they are only on in the same places as you have seen in every other case. (Some people find this demonstration works better if the dots move across the screen instead of jump back and forth. Click on the **Across Screen** button at the top of the screen to make the dots move across the screen. You can click it again, the button is now labelleed **Jitter**, to make it jitter or jump back and forth in the middle of the screen.) This is the apparent motion in movies. Going back to the original condition at 100 on the slider. you have something very different. Again, you can see the dot go off and it is not visible in the intermediate positions. What has been demonstrated has become known as the **phi phenomenon [to glossary]**. This phenomenon has been called the perception of "objectless motion". It was the study of this phenomenon by Wertheimer that forms the experimental foundation of Gestalt psychology (Steinman, Pizlo, & Pizlo, 2000; Wertheimer, 1912). Click on the button labeled **Show Hyper Phi** and see an even more compelling version of the phi phenomenon than Wertheimer studied. Here a black area seems to randomly move, and yet it is only created by turning off one of the blue squares (this demonstration is modified from a demonstration by Pizlo, 2000).

To explain the phi phenomenon and many other similar types of perceptions, Max Wertheimer with Wolfgang Köhler (1929) and Kurt Koffka (1935) developed a new comprehensive psychological theory, but we will only examine the theory as it applies to perception. In their explanation, perceptions are not constructed from sensations like Helmholtz's theory. They rejected the notion that sensations are incomplete and that they are pieced together, with or without unconscious inference. They emphasized that our perceptions are of the whole object, the gestalt. In fact, the idea of gestalt refers to the whole as more than the sum of the parts. Applying these ideas to the phi phenomenon, the whole configuration of events is perceived together to give the impression of motion. No inference is needed because the two squares are not perceived in isolation. They are seen flickering on and off as a whole configuration and in this whole, there is motion perceived between the two objects even though the motion is not part of either circle. The whole, which includes motion, is not available in the parts, the two circles (Koffka, 1935, Köhler, 1929).

J. J. Gibson took many of the ideas of Gestalt psychology and extended and modified them in such a way that his theory is really a distinct position from Gestalt psychology. Called **direct perception [to glossary]**, his theory is at the opposite end of the continuum from Helmholtz's position. For Gibson, the stimulus is a rich source of information. The senses do not send to the brain an incomplete and inaccurate information about the world that needed to be reasoned about to generate a perception. The world generates rich sources of information that the senses merely pick up, thus the idea of direct perception (Gibson, 1986). Gibson argues that the reason that scientists were led to a constructivist approach like Helmholtz's is that they used a concept of stimulus that was too limited (Gibson, 1960). The stimulus must include the context in which the object is being perceived. The context-plus-object is the true stimulus, according to Gibson. Using this much more complete view of the stimulus, there is a lot more information available to the senses than other psychologists have considered. Gibson would argue that illusions are the result of making the stimulus so limited that it is perceived in a completely abnormal context. Illusions would not be possible in a natural environment from the perspective of Direct Perception.

A very different approach to understanding perception is exemplified by David Marr (1982). By the 1970's, there had been many developments in our understanding of the brain, see below. Marr was interested in trying to use some of the specifics of what had been learned about how the brain operates to develop a theory of perception. Marr attempted to specify perception in terms of what computations the brain would need to perform the task of perception. He conceived of the brain as a fantastically complicated computer and sought a mathematical explanation. Rather than trying to describe the functions of the neurons directly, he tried to determine what computations the brain must perform. Many different types of machines can compute any mathematical expression (Turing, 1937). The logic of this approach, known as the **computational approach [to glossary]** is to try to get a computer to "see" in ways that make sense from our knowledge of the brain. Then if the computer can "see," theoretically so should the brain and it is quite possible that the brain, will also use many of the computations on the computer. Studies using this approach often attempt to simulate perception on computers. The researcher will give the computer some visual task. The task may be seeing a real object, and the computer has some form of electronic "eye" like a camcorder attached. It might also simply be a computer-generated world. In either case the computer may be give the task of identifying an object, perhaps partially hidden by another object. If the computer can do the task and, also, tends to make the same type of mistakes humans do, then those doing research following the computational approach have some confidence that they have made progress in their goal.

Each of these approaches has impacted the study of perception up to the present time. Thus, throughout this book, each approach will be used to illustrate some issue under discussion.

The Development of Neuroscience. Perhaps no field of study developed more in the last century than that of our understanding of how the brain functions. At the beginning of the century, it was not clear if the brain was actually composed of cells like the rest of the body or if it was a continuous network composed in its own unique way (Koppe, 1983). By the end of the century, we knew that the brain was made of cells called neurons, and how these neurons communicate with other; many of the regions of the brain and pathways in the brain have been identified, and techniques have even been developed to allow us to observe the functioning of the living human brain.

All of these accomplishments rest soundly on technology as well as on the ingenuity and insight of the scientists that used it. Few fields of science are as dependent upon technology as neuroscience. Many of our ideas about how the brain operates are dependent upon technology to open up those realms of inquiry. An example from sensation and perception will suffice to make this point clear. One of the more important developments in neuroscience at the middle of the last century was the development of the microelectrode. The microelectrode is a device that is so small that it can penetrate a single neuron in the mammalian central nervous system without destroying the cell. Once in the cell it can either record the electrical activity there or even stimulate the cell by carrying electrical current to the cell from an electrical source at the command of the scientist. Thus, this method allows the recording of the behavior of single neurons in the mammalian brain. It was first used in the sensory systems by Kuffler (1953). This technique led to some profound breakthroughs in our understanding of how the brain processes sensory information. Hubel and Wiesel (see 1959, 1962, 1965) are probably the names most associated with this technique. Their work not only helped us to understand the behavior of individual cells but uncovered unexpected levels of organization in the brain (Hubel & Wiesel, 1965) and information on how the brain develops (e.g., Hubel & Wiesel, 1963). Throughout this book, examples will be given of the discoveries from this method.

The usefulness of the methods like the single cell recording relies heavily on our similarity with animals. One of the many intellectual benefits that the theory of evolution brings is the recognition of our relationship to other animals. Thus, by studying other animals, we can gain clues to how our own sensory systems work at the physiological level. However, it is important to recognize the differences between human vision and the vision of other mammals or even apes. As we noted above in the discussion of the role evolution plays in how we got our senses, each animal should evolve a sensory system adapted to its environment and, thus, each animal should have a sensory system that is different. Thus, there are some important limitations on the use of methods like single-cell recording. We cannot directly examine how the senses operate in the human nervous system. In recent years, some new methods have been developed that have the promise of allowing researchers to visualize the brain during its activities in new ways. One method is the functional magnetic resonance imaging (fMRI) technique (see the appendix). This technique can image the activity levels of the different brain regions, allowing activity in the human brain to be correlated with our actual sensory abilities (Heeger, 1999). While these methods do not allow the observation of individual neurons in the human brain, they probably allow a better view of human brain activity than was possible to measure in any living brain at the beginning of last century.

Physiological studies have also led to some of the Nobel prizes given to research in sensation and perception. One went to von Bekesy who greatly expanded our understanding of the mechanisms of the ear. Hubel and Wiesel also shared one for their work on how the brain processes visual signals with Roger Sperry, for his work on the split brain.

Applications of Sensation and Perception. While the many developments in the understanding of how the brain accomplishes sensation and perception are important, many of the critical developments of our understanding have not depended at all on our understanding of the nervous system. Even though our understanding of the brain will be central to all future discoveries in the field, it is quite likely that more traditional studies of our basic sensory abilities will also be central to our understanding. One area where this is particularly clear is in the area of the applications of sensation and perception. Let us look at a couple of examples.

One of the notable accomplishments early last century was the development of a mathematical version of the trichromatic theory of color vision in 1931. The Young-Helmholtz theory was transformed into a model that made precise predictions about when two patches of color would match (see Chapter 6). This development led to many applications including the development of color movies, the first of which was released in 1939 (REF?). While we now have a sound understanding of much of the physiological basis for color vision, this accomplishment was achieved well before the actual cells responsible were identified and measured physiologically (Marks, Dobelle, Macnichol, 1964). The same set of equations is at the back of the ability of color film, color television, color computers and any other color reproduction system.

The telephone also benefits from the basic knowledge of how our hearing works. To try to justify this point, consider how much it costs for a good stereo speaker – just one. They can be quite expensive and with step up in quality, the fidelity or ability of the speaker to imitate the sound that was originally recorded increases. In addition, to get good sound out of the speaker, you need a high quality sound system with a good amplifier with good wires, etc. Now consider the telephone. It is really quite inexpensive, but part of it is a sound system just like your stereo. It has a microphone and a speaker. To make telephones as inexpensive as they are, the engineers took careful advantage of the how we hear. In short, telephones do not carry all of the frequencies that make up our voices. They can drop some out which allows for cheaper speakers and microphones. The choice of which ones to drop out is drawn from our knowledge of how the ear works. We will revisit this issue in Chapter 10.

In fact, there are many applications all around you that are dependent upon our knowledge of sensation and perception. Computers, cars, and airplanes represent three technologies that depend greatly on the study of sensation and perception. It is not an exaggeration to state that without clear application of sensation and perception, many of the technologies that we use would either be impossible or much less effective. The use of sensation and perception in the development of the equipment and tools we use is called Human Factors. Throughout this book some of these common applications will be highlighted, as they are relevant to the material being discussed.

A Conceptual Framework for the Senses

Common Events to All of the Senses

Each of the senses pick up different information from the world. Vision responds to light, touch responds to events on the skin, and smell responds to some of the chemicals that float about in the air. However, all of these senses share a vary basic commonality; they all have as their most basic function the reception of information from the environment. As a result there are some basic similarities in how the senses operate. All must be able to respond to the some feature of the environment and to convert that aspect of the environment into a form our nervous system can use. The nervous system then processes it and sends it to the various regions of the brain that use that information. It is not enough just to pick up the information from the environment; it must be meaningful and useful to us. Based upon these similarities between the senses, a very basic framework can be constructed through which the activities and events in all of the sensory systems can be related to their role in this framework and, as a result, to each other.

The Framework

Figure 1.x shows this framework. Let's us go though each step in general.

[I wonder if I can make this interactive – think on it.]

The Stimulus: Since the senses are trying to pick up information from the world around us, they are responding to events from the physical world. These physical events are called **stimuli [to glossary]**. Each sense responds to one type of physical event, and thus, the senses can be defined by the nature of the physical events that they detect. For example, our skin senses pressure, temperature and pain. Our nose picks up information from certain volatile molecules, that is, molecules that leave the object they were a part of and float in the air.

Support Structures: Many of the senses have added structures that will alter the stimulus in some way to make it more possible for our sensory systems to detect the stimulus. Most of the eye and ear are support structures. For example, light spreads out as it leaves a point on the surface of an object, going in all possible directions. It needs to be gathered back together into a point again or all of the image would be smeared. This is called focusing and it is done by lenses, whether in a camera or in the eye. **[Question, this term, support structures is my own. I don't know of a general term I can use. Is this a problem?]**

Receptors: The **receptors [to glossary]** make sensation and perception possible through the important task of **transduction [to glossary].** Transduction is a general term referring to the conversion of energy from one form to another. The information in the environment is in a form that our nervous systems cannot directly use. So the receptors are specialized nerve cells that can take energy from the environment and convert it to a form that can be used by the nervous system, which is the change in voltages at the membranes driven by chemical events (see the Appendix). It was noted above that each sense could be separated by the type of stimulus it responds to. It is the receptor that is responsible for this classification of the senses by the type of stimuli. The receptors of the eye respond to light, the pressure receptors in the skin respond to pressure, and the taste buds in our mouth have cells that can respond to some of the molecules of our food. If we do not have a receptor that can pick up a type of energy or information in the environment; then that event, in a very real sense, does not occur for us as was discussed earlier.

Neural Relays and Pathways: When the signal leaves the receptor, it begins to travel to the brain; and, for most of the senses that we will consider, the information from the stimulus will end in the top outer layer of the brain, the cortex. The trip to the brain is not a simple, passive sending of signals from the receptor to the brain. The nervous system signals derived from the stimulus are processed along the way to the brain. For example, pain is processed in the spinal chord before traveling to the brain. It may be that the signals are weakened so much at the spinal chord that the pain becomes much less severe (see Chapter 12). In addition, the senses play many roles in our functioning in the world. Touch can let us know if something is pressing on us or help us to determine the shape of an object or even help us to keep our balance (at least the base of our feet play this role from touch). Since these roles can be so different, it should not be surprising that more than one part of the brain will need to have input from touch. What is true for touch is true for all of the senses: each sense goes not to one location in the brain but to several. Each part of the brain will process the signals from the stimuli in the way it needs to get the information it needs. In this text we will emphasize those regions of the brain that lead to our experience of each sense. These brain locations are call the primary brain cortex for that sense. So there is a primary touch cortex and a primary auditory cortex. Still, we will have the opportunity to mention some of the other brain regions when they are relevant to our discussions and comparisons with other animals.

Cortex: The cortex is the most sophisticated region of the brain. The senses have target locations in the cortex called their primary cortex. But this region is really just a starting point for the processing of the sensory signals. As was mentioned above, sensation and perception cannot be clearly distinguished from each other, but it is clear from **Interactive Illustration 1.x (Old/Young Woman)[NOT DEVELOPED YET]** that information from beyond our senses impact how we experience the stimulus. Thus, sensory information will travel to other regions of the cortex, where the sensory information can be combined with our cognitive processing. In addition, it will be clear that cognitive processing will affect what happens in the primary cortex for each sense. As with the demonstrations, what goes on in the primary cortex is a combination of bottom-up and top-down processing.

Perception: With the arrival of the information in the cortex, we begin to see that information other than just what is provided by the basic signal is becoming involved. Remember **Interactive Illustration 1.x (the old/young woman) [NOT DEVELOPED YET]**, and **Interactive Illustration 1.x, What is this Figure?** These figures illustrated that to understand completely how we know about the world, we must discuss some of the ways that the context and our own experiences can affect what we see. This is the world of perception. Often in this case, the physiological basis of the experience is at best little understood. So the explanations will be more in terms of our understanding of how we respond at the level of our behavior to these stimuli under different conditions. Try the example in **Interactive Illustration 1.xa** and **1.xb, Visual Search**. In both cases click on the start button and try to find **Y**. All the rest of the figure is taken up by **X**'s. In one case, it is very easy to find the **Y** and in the other it is much more difficult, and yet, the **Y**'s are identical. We will need to examine these types of issues in more depth (see Chapter 16).

How the Framework in Used in this Text

If information is organized, it is often easier to remember. Recall the material about elaborative processing and the Levels of Processing material from introductory psychology (Bartlett, 1932; Craik & Lockhart, 1972). It is best if you develop your own organization, but it is often easier if an organization is already provided. The framework that was presented in the last section will provide an overall organization for the material as each sense is covered. In each case we will follow the path starting with the stimulus (Figure 1.x). With each step in the framework, the information becomes more complex, so we will gradually add another layer of complexity as we travel up each sensory system. Finally, with the discussion of perception, it will become clear that our experience of the world is not a simple bottom-up process but is two directional involving the bottom-up information starting with the stimulus and using the top-down information of context and cognition.

Another way that this framework will help to organize the material in this text is that it will facilitate comparisons between each sense. Since each of these senses perform common tasks, you can apply what you have learned about one sense to what you are learning about another sense. Every sense has a receptor that performs transduction. Once you have covered one sense you can compare the receptors and the way they accomplish transduction between them. By looking for commonalities you can keep the material better organized and make it easier to learn. In some cases, even how the sensory systems operate on a fairly detailed fashion can be compared. Both taste and smell respond to chemicals, so the way that they respond to the stimuli should be related. Knowledge from one sense can facilitate learning about the same action in the other sense.

How to Use this Text and the Media

[This is very sketchy as a lot of this section will ultimately depend upon the media that is developed.]

As mentioned in the first section, this book uses media in a fairly new way. Most of the figures, even in this introduction, are based on a CD-ROM/Web, so you need to have a computer handy as you read this book.

The media that accompany this book are of the following types:

1. Interactive Illustrations, e.g. **Interactive Illustration 1.x, the Phi Phenomenon**. In these you will interact with some figures that allow you experience directly an aspect of our sensation and perception and that give you feedback based on your responses.
2. Interactive Figures, e.g. **Interactive Figure 3.x**, the diagram of the eye. These illustrations will allow you to work with some figures and also to test yourself on your knowledge of the information illustrated in the figure. [**do we want an option where the students test can be sent to the instructor?]**
3. Interactive model or theory, e.g. **Interactive Model 2.x** about the signal detection theory. To help you understand some of the more abstract concepts in the explanations for sensation and perception, there are several figures that will take these concepts and make them more concrete. You can actually manipulate inputs into the theory or model and see how it predicts we will respond.
4. Experiments, e.g. **Experiment 2.x**. In some cases, the demonstration or model will have you collect data. These data will be collected by a central database and be accessible to your instructor (and you?) during the rest of the term. In these experiments you will be able to see and practice how data is collected and analyzed using several of the methods that have been used in sensation and perception.

Summary

In this chapter, the basic concepts of sensation and perception were introduced. The first figures were included for two reasons, to illustrate the way that media will be used in this text and to show the subtlety and complexity of the processes of sensation and perception, which makes them very interesting to study. From this introduction, I introduced the concept of the senses being adapted to serve our needs and not merely copy the world. Next, a simple historical perspective, including some of the theoretical perspectives of the study of sensation and perception, showed the development and context for the modern study of sensation and perception. These theoretical perspectives include the constructivist approach, Gestalt psychology, direct perception, and computational approach. The role the study of the nervous

system and the applications of sensation and perception indicated the diverse range of issues impacted by the field. Next, a conceptual framework to organize the material in this text was introduced. This framework starts with the stimulus, went to the support structures, to the receptor, to neural pathways, to the cortex and perception where events move both in bottom-up and top-down directions.

Key Terms

Figure 1.x. Newton’s prism experiment

Figure 1.x. Vase or two faces?

Figure 1.x. A conceptual framework for the senses.