Chapter II

SCIENCE AND COMMUNICATION

There is no single correct approach to the study of communication. To a musician, communication may be the way music brings about reactions in both players and listeners. An artist may think of communication as all the ways a work of art affects those who experience it. A public speaker might define communication as the process by which he or she rouses an audience to action. An engineer could think of communication as a process whereby information is carried along some channel, while a physicist might see the transmission of energy between the sun and the earth as a form of thermodynamic communication. None of these ideas of communication is wrong, nor, in any absolute way, is any of them better than the others; they simply represent the different ways different people engaged in

different activities think about the aspects of the world that are important to them.

Communication is one of the broadest topics on earth. By some estimates, half the people in the world work in a communication related job, and in industrialized societies, perhaps two thirds to three quarters of all people's jobs are jobs in communication. It's not surprising, then, that there is no single way of studying communication that is best, but that different ways are appropriate for different aspects of communication.

The field of Communication is really a loose collection of many specific disciplines, such as Journalism, Debate, Rhetoric, Theater, Mass Communications, Radio and Television, Communication Theory, Telecommunications, Speech, Speech Therapy, Audiology, Communication Disorders, and many, many, more. And, just as there are many specific disciplines, there are many different approaches to the study of

communication, even within each discipline.

As Alfred North Whitehead once said, in order to know anything, we must first give up the hope of knowing everything, and this is especially true of communication. No one can hope to be expert at all aspects of a topic as broad as communication, and so, in this book, we are concerned with only one aspect of communication: the scientific study of communication.

Science as Public Understanding

Science is a way to understand our experience. It is not the only way, nor is it necessarily the "best" way for any person in any situation. Other approaches, such as art, music, philosophy, religion, mythology, and others produce different kinds of understanding which fill other human needs. In this book, however, we are concerned solely with scientific approaches to understanding communication.

Few topics have been the object of as much confusion and misunderstanding as science. The great achievements of modern science, and the extensive control (for good or ill) over our environment that have resulted from modern technology, has led many to try to extend the scientific method to virtually every aspect of human inquiry. It has also led many to claim their method of study is scientific when it is not. And it has led still others to rise in opposition to the overextension of science to areas in which they believe it does not belong. This is true within the field of communication as well as elsewhere, so that some communication students claim that the methods they use, while different from those used by other scientists, are nonetheless "scientific," while others claim that communication ought not or cannot be studied by scientific methods.

These debates have sometimes produced more confusion than clarity, and have led many to use the

word "science" to describe methods that are anything but scientific. Before beginning a study of Communication Science, then, it is important to begin with a clear definition of what science means.

We begin by acknowledging that science, as an ordinary word in English, has many definitions and means different things to different people. A word is just a word, and anyone is free to mean whatever they wish by any word. You might decide, for example, that you will choose to mean "foot" whenever you say "hand," and that you will mean "hand" whenever you say "foot." So to you an attractive man will be footsome, delicate material will need to be footled with care, your house will be maintained by a footyman, you might camp at the hand of a mountain, and the Buffalo Bills will be a handball team. In a pluralistic society you have the right to do this, and no one may say you are wrong. But you will have some difficulty communicating with others.

To be useful as a tool for communication, a

word must be defined in similar ways by those who use it. The purpose of defining a word or concept is not to find the "true" meaning, because there is no true meaning. Instead, we agree on a common definition for a word or concept so that we can communicate with each other without confusion. As we will see, to become a scientist is to join a community of scientists and work collectively. We are interested not in any "true" definition of what science "really is", but rather in what *scientists* mean when they say "science." You may, of course, decide to define science in your own unique way, and you may have very good reasons for doing so. But when you speak to other scientists, they won't know what you mean, and your attempts to communicate will fail.

This is particularly important in the study of human communication, because many human communication researchers use procedures and methods they consider scientific, but which scientists in older,

established disciplines such as physics, chemistry, biology, astronomy and the like would not consider scientific. In this book, we will try to define the essential characteristics of science in a way that is acceptable to established sciences, such as physics, chemistry, biology, and astronomy. We do not mean to imply that each different science uses exactly the same methods, but we do insist that the most general principles of science must be the same for any discipline that calls itself a science; otherwise the use of the word science will confuse us rather than help us.

One school of thought within Communication believes that science as it is defined by "physical" scientists cannot be applied to human individuals and organizations, and that a different definition of science should be applied to human communication. While there may or may not be good reasons for using different methods for studying human communication and physical processes, it may not be wise to describe

these different methods by the name "science," because it tends to make other scientists think communication researchers don't know what they're talking about.

In order to understand better what scientists mean by science, it may be worthwhile to understand some of the more general uses of the word in English. *Webster's New Collegiate Dictionary* (1974 Edition) lists five general definitions for the word "science." The first (most common) definition simply considers science to mean knowledge as distinguished from ignorance, or knowledge attained through study or practice. The second most common definition considers science a department of systematized knowledge. (The dictionary gives the "science of theology" as an example, but few scientists would consider theology to be a science.) The fourth is a system or method purporting to be based on scientific principles, and the fifth is Christian Science, an informal name for the Church of Christ, Scientist.

It is no criticism of these uses of the word

"science" to say that they are not what a scientist means by the term. A practiced ballerina or pianist has great knowledge attained through practice, but many ballerinas and pianists might be insulted to have their art considered "merely" science. Many, and perhaps most, theologians would assert that their knowledge goes beyond what can be discovered by science alone.

Webster's third definition comes closest to what scientists might mean by science, that is, knowledge about general truths or natural laws, especially as obtained through the use of scientific method. Webster's defines "scientific method", as "...principles and procedures for the systematic pursuit of knowledge involving the recognition and formulation of a problem, the collection of data through observation and experiment, and the formulation and testing of hypotheses."

Webster's dictionary may serve as a useful guide to the common meanings of words in English, but

should not be considered an authority on technical, scientific terms, including the meaning of the word "science." Nevertheless, certain general characteristics of science can be found in this definition. Two main characteristics should be emphasized. The first is the **kind** of understanding science seeks. The second is the **method** by which scientists seek this understanding.

Classical Science

Science has always striven to produce general, shared understandings rather than specific, personal understandings. While Galileo spent a great deal of time and attention examining how a specific ball rolled down a specific board, he was not really interested in that particular ball or that particular board, but rather in how any body or object falls anywhere, any time. Further, he was not interested in a description that was satisfying to him personally, but rather he wanted to

produce findings that could be confirmed by other scientists. He wanted to produce ***general*** knowledge about which all other scientists would ***agree***.

This is very different from the kind of understanding a great artist such as Bach, for example, tried to create. While it is certainly true that great music such as Bach's touches at elements that are universal and general in all people for all time, each person, nonetheless, finds in his music something unique and personal, something which changes with each listening. Mendelssohn's *E flat Violin Concerto*, for example, is perhaps the most popular violin concerto in the current repertoire. Since the violin repertoire is much smaller than the piano literature, a virtuoso violinist typically will be called on to perform this work many times throughout his or her career. Although the greatness of the work comes in large part from the universal elements it contains, nonetheless a great challenge for the artist is to find new meaning and fresh

interpretation for this work each time it is played.

Galileo's law of falling bodies, however, is meant to be exactly the same for any object, viewed by any observer, at any time or place. Fowler's *Dictionary of Modern English Usage* emphasizes the notion of general truth as a component of science as compared with art, and says that the facts of science are the same for all people, circumstances and occasions, but that art varies with the artist and the task. This is not to say that Galileo was greater than Bach -- only that he was different.

Galileo's great experiment which established his law of falling bodies provides a classic example of what it is science strives to achieve and the method it uses to achieve it. Before Galileo, motion -- the way things move -- was considered very mysterious. The philosopher Aristotle had proposed some laws of motion about 1800 years before Galileo. The most well known of these laws said that objects would fall with a velocity

proportional to their weight. Thus, a ten kilogram object would fall ten times as fast as a one kilogram object, and a 100 kilogram object would fall 100 times faster than a 1 kilogram object, and so on.[1] For about 1300 years, no one concerned themselves much with the laws of falling bodies; most philosophers believed that motion was a spiritual rather than a physical phenomenon. But in 1066, at the Battle of Hastings, gunpowder was introduced into Western warfare, and from that time on, military people and scholars began to pay attention to motion, particularly the motion of what

[1] This law is not only false, but it is false by a very large amount. You can prove this to yourself quite easily. Find two objects, one of which is quite heavy, and another of which is much lighter (a book and a piece of chalk will do). Stand on a table or desk, pinch both the objects between your fingers and let go of both at once. You will see that both fall at the same velocity, and strike the ground together. Repeat this experiment until you are convinced that Aristotle's law is false.This brings up an interesting question: If Aristotle's law is so clearly false, and so easy to prove false that a student can do so in a few minutes with ordinary material that can be found anywhere, why did it take the most brilliant scholars in the entire world 1800 years to discover that it was false? (If you don't find that a fascinating question, you may not be cut out for a career in science.)

we now call "ballistic" objects, such as shot fired from cannon, because they needed to know how to tilt and point the guns so that the shot would fall on the target.

For several hundred years, thinkers used philosophical and mathematical methods to try to understand ballistic motion. They applied reasoning (like trying to deduce how shot should travel from Aristotle's laws of motion) to the problem, but did not make systematic observations. The result was some curious concepts of how cannonshot travelled.

At the end of the sixteenth century, Galileo began to study this problem systematically. As we have said, earlier scholars had studied motion systematically, but Galileo's approach differed in that he employed *observations* in addition to reasoning. Common folklore says that Galileo dropped objects of different weights from the Leaning Tower of Pisa, but most scholars doubt this is true. There is good evidence, however, that Galileo did observe falling objects in a systematic way.

But in the late sixteenth and early 17th Century, when Galileo was conducting these experiments, accurate clocks had not yet been invented, and free-falling objects fall so fast that it is difficult to time them accurately. Galileo ingeniously realized that he could deal with this problem by studying objects that were falling, but not freely. He spent a good deal of time observing *pendulums*, which are objects whose falling is controlled by a line or rod which forces the bob (object at the end of the pendulum) to fall along an arc. Galileo is supposed to have timed the swinging of pendulums by counting his pulse beat while observing, and was able to find that the rate at which a pendulum swings (falls) seems to depend only on the length of the pendulum line, and that the rate at which a pendulum swings does not appear to depend on how heavy the bob or weight might be. His findings contradict Aristotle's law.

Among the many experiments he conducted was

his famous "inclined plane" experiment. In this experiment, Galileo set up a long plank with a groove cut down its center from end to end. He raised one end of the plank, and placed a small ball in the groove at the raised end of the plank, and observed it as it rolled down the incline. (You might recognize that the inclined plane serves the same function in this experiment as the line of the pendulum.) In order to find out how fast it rolled or "fell" down the plank, Galileo needed to keep careful track of time. This was quite difficult, because the best clocks in the world at that time were only accurate to within a few hours per day. No one knows for certain how Galileo kept the time, but the best guess seems to be that he did so by singing. Galileo's father was a professional musician, and Galileo himself was a talented amateur musician, and a good musician can keep time with remarkable precision. As the ball rolled down the plank, Galileo chanted rhythmically, and made a chalk mark at the location of the rolling ball exactly

on each beat. He then place a moveable fret (like an elastic band, or capo often used on guitars to raise the pitch) at each mark. He then rolled the ball again and again, each time adjusting the exact location of the frets until the ball bumped over the frets exactly on each beat.

Once the frets were perfectly positioned, Galileo could simply measure the distances between the frets, and he would know *exactly how far the ball rolled for each "tick" of his musical clock.* From this information, it was possible for Galileo to deduce that the distance the ball rolled was proportional to the square of the time it had been falling.[2]

It's very helpful in understanding science to understand the *goal* of Galileo's experiments with falling

[2] You should not be content to read about this experiment. You can easily repeat it for yourself in about a half an hour. Try varying the size of the ball and the steepness of the incline. If you don't feel a special emotion while repeating exactly the same steps as Galileo -- and checking his work! -- science may not be for you.

bodies. Every falling body is different, and every instance of the same body falling is different. The *meaning* of falling is different in every instance. When a cannonball falls it may mean war; when leaves fall it may mean Autumn; when you fall it may mean injury. Furthermore, any specific case of something falling may be so complicated that no amount of scientific scrutiny could ever unravel just exactly what has happened or how it happened. When a leaf falls from a tree, for example, it obeys all the laws of motion, yet its path is the result of so many factors that it is technically impossible to predict or even describe its falling with any precision at all.

But Galileo was not interested in any of the unique elements of falling. He was only interested in what could be said about all falling bodies at all times, regardless of their differences. The essence of science is to penetrate through the specific complicated detail of everyday experience and discover the simple and general

processes which underlie all the obvious complexity. Galileo was interested in discovering a *general law of falling bodies that expressed the distance they would fall as a function of time.* To do this, he tried to discover only those aspects of falling that were the same for all falling bodies, and ignored those aspects that differed from case to case. This process -- finding the universal aspects which exist in all specific instances -- is called "abstraction," and it is *abstract* knowledge which is the goal of science. A statement that makes no reference to any *specific* thing, but rather refers to characteristics that are common to many specific things, is called "abstract." A statement that admits of no exception, but which is always true or always false, is called "universal." Science seeks to make *abstract, universal* statements about our experience; these abstract, universal

statements are sometimes called "laws."[3]

During this same period of time, great astronomers like Tycho Brahe, Copernicus, and Johannes Kepler were making careful and precise observations of the motions of the sun, moon, and planets. Their goal, like Galileo's, was not only to provide a careful record of what they actually saw, but to move beyond their observations to a universal, abstract principle that would explain all the observations. Aristotle had said that these "heavenly bodies" always moved in perfect circles. Although

[3] In the past, many scientists were quite optimistic about discovering universal, abstract laws of nature that would be true once and for all. But several centuries of careful study have led most modern scientists to develop a more humble attitude; while we still speak of laws of nature, scientists generally believe that science does not ever succeed in finding the ultimate, final laws of nature, but rather continues to reject older "laws" and replace them with more powerful, more accurate "laws" which themselves are subject to be replaced again as our understanding deepens. Complete, final, certain understandings of our experience are more appropriate to theology than science, and scientists in general believe that all our theories must always be considered tentative, subject to rejection later on the basis of more complete and more accurate observations.

astronomers had been observing these bodies for thousands of years before Aristotle, none of their observations were precise enough to show whether the heavenly bodies moved in circles or not. But Aristotle believed they did, but for completely philosophical or religious reasons. He believed that circles were a "perfect" form of motion, and he believed that everything in the heavens was perfect; thus, all heavenly bodies must move in circles.

Brahe's observations were accurate enough to show that the planets did not move in perfect circles, but rather in slightly elongated circles called "ellipses." Moreover, Kepler examined these ellipses with enormous care and dedication. (Good scientific work is not brilliant people making brilliant deductions -- it is careful and diligent observation, checking and rechecking, sprinkled with occasional brilliant deductions; as George Barnett says, "Science is difficult.") He knew that, if one observed the position on

the ellipse of a planet at two different times, and drew straight lines from these two positions to the center of the ellipse, they produced a "sector" which looked like a piece of pie. He also observed that, if the length of time between measuring the position at one time and measuring it at another time was kept the same, the *areas* of the resulting pieces of pie would be identical. This seemed to show that there was something universal underlying these specific concrete motions.

Almost one lifetime after Galileo's great discovery, Isaac Newton understood that the elliptical motions studied so carefully by Kepler contained within them two specific motions. One was a motion perpendicular to a line drawn toward the center of the sun or earth, while the other was directly along that line and toward the sun or earth. In fact, the planets were moving exactly sideways relative to the sun while at the same time falling directly toward it; the moon was similarly moving directly sideways relative to the earth

while also falling straight toward it. As a result of the sideways motion, the planets always "missed" the sun while falling toward it, and the moon always "missed" the earth while constantly falling toward it. After careful study and a great deal of calculation ("Science is difficult") Newton was able to develop a set of universal, abstract laws that were even more general than Galileo's, because they explained not only falling motions, but all motion whatsoever. Galileo's law of falling bodies, as well as Kepler's law of equal areas, are both explained by Newton's more general laws of motion.[4] Thus, an important goal of science is not only to form universal, abstract laws, but to strive to find ever more general universal abstract laws, with the goal of explaining more with fewer laws.

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[4] It is important to notice that Galileo's law of falling bodies was not rejected in favor of Newton's laws of motion because Galileo's law was found to be false, but rather because Newton's law explained everything that Galileo's theory explained, plus more.

Modern Science and Relativity

In the early part of the 20th Century, scientists began to realize that Galileo's Law of Falling Bodies, along with Newton's more general Laws of Motion, did not appear to be true for all observers at all times; rather the rate at which bodies moved relative to each other seemed to depend on the *frame of reference* of the observer. Observers who viewed moving objects from standpoints that were accelerating relative to each other would not observe the same relative movements of the bodies observed. This caused a crisis in the scientific community which has repercussions even today.

The most widely accepted solution to this problem was proposed by Einstein, who wrote a set of equations which could transform the observations made by one observer so that they would appear the same as those made by another observer in another reference frame. These equations form the core of the General

Theory of Relativity. Although a discussion of relativity theory is beyond the scope of an introductory book, the ideas of *relativity* and *transformation* are essential to understanding science and how science can be applied to the study of communication.

Relativity and Transformation

By now it is well known that no two people experience the world in the same way. Each person is born with senses and a brain that, while generally similar to those of others, are nonetheless unique. As each of us grows older, we learn languages, experience emotions, and make friends, all of which form us into increasingly unique individuals. The world we experience is filtered through our languages, beliefs, attitudes, emotions, and all those other factors that make up our unique *frame of reference*. When we are growing a garden, the rain is welcome; when we are planning a

picnic, it is not. When we are lonely, a visitor may be a joy; when we are busy, the same visitor may be unwelcome.

Not only what we feel, but what we see, hear, feel, smell and taste depends on our frame of reference. Eyewitnesses to an event almost never agree on what they "saw" and "heard;" one person may find a room too cool, while another in the same room may find it comfortable or even too warm. If an observer on a moving train drops a ball to the floor of the train, the ball will seem to that observer to fall straight to the floor. But an observer standing outside the train will observe the ball falling sideways as well as down, to form a parabola. These differences in perception are not unusual, but typical. Observations depend not only on what is observed, but also on the frame of reference of the observer. Because no two individuals ever share exactly the same frame of reference, no two observations made by different observers will ever agree

completely.

What's more, when two or more observers attempt to *compare* their observations, another difficulty crops up. To compare our observations, we must communicate with each other; each of us must describe our observations to the other, and we may each then compare our descriptions. *It is very important to realize that it is never our observations that are actually compared, but only our descriptions of them.* The direct comparison of observations made by one person with those made by another is impossible. Because of this, the experience of each person is always fundamentally private, and can only be shared with other persons in an indirect way, through communication. Communication lies at the core of science.

Some Communication theorists believe that scientists are naively unaware of the effect of individuals' reference frames on their observations. They accuse scientists of falling into an old philosophical

position called "positivism," which (roughly) holds that we can experience the world directly and see what is "actually" there. Positivism also implies that the same phenomena will appear the same to any and all observers. These theorists, contrary to positivists, believe that the filtering effect of the unique reference frames of each individual means that each person lives in a unique reality, and attempts of scientists to produce general, universal understandings of the world which are shared among observers are doomed to failure.

In fact, scientists are much more sophisticated than that, and have long been aware of the relativity of human experience. Einstein, for example, early in the 20th Century pointed out that only through the aid of language were we able to communicate about our experiences, and only those experiences about which we agree do we call "real." Einstein knew, as most modern scientists know, that *communication* plays a vital and central role in science. The great physicist Niels Bohr

once said that science is the process whereby we make observations and communicate them to others who must check them.

Scientists know that each individual sees the world differently. But a main goal of science is to find ways to produce *common* frames of reference so that they can produce a single, common understanding of the world. While scientists generally agree that individuals make observations that are influenced by their individual frames of reference, they also believe it is possible to find relationships between each of these private frames of reference and *transform* the experiences from one reference frame to another. These transformations may be quite complicated in any specific instance, but the fundamental idea of transformation is very simple. If we understand the way one reference frame is related to another, it is possible to find rules that will indicate how an observation made within one frame of reference would have looked had it been made in another. If such

rules or transformations can be discovered, then it becomes possible to compare the unique individual experiences of one observer to observations made by another. In this way, science attempts to forge a single, **public** understanding about which we can agree, from the many private understandings of individual observers.

This is the fundamental goal of science: *to develop a shared, public understanding of our observations.* The process by which science strives to produce one common *public* understanding out of the many individual *private* understandings makes up what we call the "scientific method."

Scientific Method

Almost every elementary school student, at least in the United States, has at one time or another studied "the scientific method," which is usually described as a

series of four steps first described by Francis Bacon in the 17th century. What we are concerned with here, however, is not so much a brief description of general procedures used by scientists, but rather the fundamental method of approaching experience that distinguishes scientific research from all other forms of human inquiry. Scientific method in this sense is not so much a series of steps as an abstract process for discovering general, universal, abstract understandings of our experience. As such, scientific method is more of a way of understanding than a series of steps or procedures. Science is a process with a goal, and scientific method is a way of making progress toward that goal. Unless you understand the goal of science, you will not understand its method. Above all, the goal of science is to find universal, abstract understandings of what we observe, about which all observers will agree.

Observation

First and foremost, scientific method begins, therefore, with *observation*. Aristotle's law of falling bodies is indeed a universal, abstract statement that attempts to explain the motion of falling bodies. But it fails as a scientific proposition because it is neither based on nor verified by observations. Aristotle derived his law of falling bodies by reasoning alone, not from observations, and was so certain he was right that he did not believe it necessary to make observations to confirm the truth of his proposition.

The idea that our beliefs ought to conform to observations we can make is an essential part of science, but not of every system of knowledge. As we saw earlier, Aristotle's law of motion is easy to falsify, yet the greatest minds of Europe continued to accept it for 1800 years. Some methods of gaining knowledge specifically believe there are ways to gain knowledge

that do not involve observations. Many religions, for example, hold that *faith* is a legitimate basis for knowledge, and that important truths may be revealed to prophets and even ordinary faithful, directly by God. Christianity, for example, holds that the most fundamental truths are accepted by faith, and cannot be discovered by observation nor confirmed by observation.

Some philosophies, such as the philosophy of Plato, hold not only that observation is not important for discovering knowledge, but that it is positively harmful. Plato, for example, believed that the bodies we inhabit and the world we live in are corrupt "shadows" of the true "world of ideas." Because what we learn through the senses of our corrupt bodies about the distorted world we live in is bound to be in error, Plato recommends that we ignore the world we live in and instead concentrate our attention on inward reflection and contemplation, particularly as aided by dialectical argument with other philosophers as a means of gaining

"true" knowledge. Many people all over the world accept this philosophy or one like it, but, whatever might be the merits of such a system of knowledge, it is completely different from scientific knowledge, and its methods are completely contrary to scientific method.[5]

Other people believe for religious reasons that observations are either unimportant or harmful. When Galileo, for example, brought the newly invented telescope to religious thinkers and invited them to look though it to see that the moon was not a perfect unblemished sphere and that Jupiter had moons (observations which contradicted much of what these religious scholars believed), many of them refused to look into it, because, they said, they knew that Satan

[5] Remember, this is not to say that Platonic methods are of no merit -- that is a judgment you must make for yourself. But it is to say that Platonic methods are completely different from what scientists call the scientific method, and if you choose to call Platonism "scientific," you will not be able to communicate with scientists very well.

could make them see whatever he wanted, and so looking would only confuse what they already knew to be certain. It's easy to understand how people who accepted such a philosophy could fail to discover that Aristotle's law of falling bodies was wrong, even for 18 centuries. Moreover, it also explains how it is possible to continue to believe something which is contradicted by observations -- something which is contrary to the scientific method.

Objectivity

While observation lies at the core of scientific method, there is more to scientific observation than simply looking carefully at the world. As we have seen, the observations of individual people are subject to all kinds of both systematic and random sources of variation from one person to another. In order to make observations that are, as far as possible, free from these

individual observer effects, it is necessary to *invent public ways* to make observations. One person might measure the time it takes for a certain process to finish by his or her own internal feeling. Another might count his or her pulse beat; a third might count numbers, while a fourth might estimate the changing angle of the sun. Each of these different methods of measuring time will probably give a different result from the others. Because these observations can not be compared to each other, from a scientific point of view, they are not only useless, but they are worse than useless, as they not only don't provide useful information, but give the false impression that something is known that is not. Inventing ways to make observations and forming agreements about how to make observations is one of the most important functions of science.

To be useful as scientific observations, observations must be made according to a method that has been invented, discussed, shared, and agreed upon,

so that one observer can take the place of another and carry out the same observations. Only when standard methods of observation have been developed and agreed upon can the observations of different observers be compared.

Science is a collective effort to develop shared, public knowledge, and so it requires that observations be made in a public way. Newton developed his theory of motion from observations, but he himself did not make the observations on which his theory was based, nor did he perform the observations that later verified it, or the observations that, still later, established its limitations. Instead he relied on observations made by Ptolemy, Copernicus, Tycho Brahe, Kepler and others, but that were available to him to study. These observations were available to Newton because they were *public*. But we mean "public" in a very special way.

The observations of the astronomers that informed Newton's thinking were not all public in the

everyday sense of the word; many, in fact, belonged to different people and agencies, and only a few lucky individuals of the day were privileged to gain access to them. But they were public in the sense that they were not written in a secret code (as were the notebooks of Leonardo da Vinci, for example), nor were they the private insights of special intuition that only the original observer could understand. A great poet or religious mystic might, for example, have insight into deep and intensely personal understandings that could not be fully communicated to another human being, no matter how hard one might try. But the observations of Tycho, for example, were performed with instruments that could be accurately described -- so accurately that another skilled artisan could build essentially identical instruments. And the method -- the actual procedures -- by which Tycho made the observations could be described accurately enough so that another skilled observer could understand exactly how he made them, and could in fact

repeat them. Moreover, the observations themselves were written down in a public code, using commonly defined words and symbols. Science strives to develop methods of observing that are so public and so well described that *it does not matter who makes them.*[6] Because they are public and made by methods well understood by the scientific community, observations made by one astronomer could be understood by another, and observations made by many astronomers could be combined to produce a much more complete picture that accumulated over time. In this way, the observations made by one scientist could be shared by another, and this is the sense in which scientific

[6] This is the scientific meaning of "objectivity." Observations are said to be "objective" when they are not influenced by the person or persons who made them. By contrast, when what one sees depends on personal characteristics of the observer, they are said to be "subjective." A main purpose of scientific method is to make observations independent of the observer, and thus "objective." Some communication theorists believe it is impossible to eliminate subjectivity from observations, but most scientists believe that it is.

observations can be called "public." Because they are public, we can *compare* these observations, and produce not a series of special, unique, individual understandings, but a single, general, public understanding.

Because this public body of observations existed, anyone proposing a theory like Newton's would have to show that the predictions of the theory were consistent with the many public observations already available. A main part of scientific method, then, is the *collective production of a set of public observations against which any proposed theory must be judged.* It is not enough, then, to speak of observations; science requires that observations be *comparable*, that is, public.

Precision

Anyone, of course, can make an observation, and even write it down. But some observations are more

trustworthy than others, and it is a fundamental requirement of the public observations of science that *no observation is to be recorded without a reliable estimate of how trustworthy it is.* As E. Bright Wilson says, a measurement whose precision is completely unknown is of no use whatever.

The orbits of the planets, as we have said, are elliptical, not circular. But they are *very nearly* circular, and, in fact, Kepler was able to compute a perfectly circular orbit for the planet Mars that fit Tycho's observations to within 10 minutes of arc. But, as Tycho's assistant, Kepler knew that Tycho's observations were accurate to within about 5 minutes of arc, so he had to rule out the possibility that the orbit of Mars was a circle. The circular orbit was not within the range of observational error, and so had to be rejected.

Part of the character of the accumulating public record of observations that make up science is that they not only become more numerous, but that they become

more precise. Every measurement or observation is always wrong to some extent; nothing people do is perfect. Precision refers to the *margin of error* around any measurement. A major goal of science is to reduce the margin of error around the observations that make up the public body of scientific observations against which scientific theories are to be evaluated. As the these margins of error are reduced, the severity of the test that any proposed theory must meet is increased, so that theories that once were within the margin of error of the existing body of observations are found to be in error when gauged against the more precise observations. In this way science strives to produce not only more general theories that explain more observations, but also more precise theories that explain more observations to within smaller and smaller tolerances.

Theory

The examples of theory given so far are wonderful examples, and among the most successful and useful theories science has ever developed. But a theory does not have to be as general or useful as Newton's General Theory of Motion in order to qualify as a useful and successful scientific theory. In the usual case, a theory is an hypothesis or set of hypotheses about how certain observations are related to each other. Communication theorists have developed theories about television viewing, for example.

Since television began, many people have accumulated a great number of observations about who watches, when they watch, what they watch, and so on. Certain relationships among these observations have also been noted; men tend to watch some kinds of shows more frequently than women; people watch more TV in winter than summer, and so on. Different

scientists have invented different theories to explain these observations. One theory, the Uses and Gratifications theory, hypothesizes that people watch television because they anticipate gaining something they want or need from it. Another more recent theory hypothesizes that people watch television "by default," because there isn't anything else to do. Neither of these theories is even remotely as general or important as Newton's theory, but they are, nevertheless, theories. A theory doesn't have to be correct or wise or important to be a theory; it is entirely possible to have foolish and useless theories -- in fact, most theories turn out in the end to be wrong.

Both these theories could be derived from still more general theories. The theory that people watch television to gain some gratification can be derived from the more general theory that says that people perform any action whatsoever in order to gain some gratification, which is one of the most general and

commonly believed theories of human behavior that exists. The "default" theory could be derived from another general theory of human behavior, the "pattern matching" theory, which hypothesizes that people do those things they believe are appropriate for people like themselves whether they are gratifying or not. If we assume that society generally defines television viewing as an appropriate activity for those who have nothing else to do, then the general theory predicts people will view television "by default" when no other actions are available.

Testing Theories

Both of these theories claim to explain observed television viewing patterns. If one of them turned out to

be correct,[7] it would be possible to use the theory to predict future viewing patterns, which could be very useful for many people. It might even turn out to be possible to *influence or control* future viewing patterns based on information from a good theory. It is important to test these theories to find out whether either of them explains television viewing well enough to be worth keeping, and, if so, which one is better.

A good deal of scientific information about television viewing is available. For several decades, television networks and polling companies have been compiling figures about the number of people viewing television at all times of day and night. This information

[7] Or at least fairly close to correct, since many theories are only approximately accurate in many circumstances, even though it is the goal of science to create theories which are as accurate as possible. Many theories are known to be inaccurate in their explanations or descriptions of observations. But theories are not rejected simply because they are known to be wrong. A good theory can still provide useful approximate explanations and predictions even if it isn't perfect. A theory is only rejected when a better, more accurate theory is available.

is not public in the ordinary sense of the word, because it belongs to the companies that have collected it. But, it is "public" in the sense that all scientific information is public: that is, the observations were made in a standardized way that is understandable by any scientist familiar with modern polling methods, and can be understood in the same way by any scientist who views it.

One way the two theories about television viewing might be tested is to see what they predict about television viewing patterns of people, and compare these predictions to the public data base of television viewing. Several scientists have examined these data quite carefully, and shown that the number of people viewing television at any time is extremely closely related to time of day, day of the week, and season of the year. This pattern of observations is very much like the pattern that would be predicted by the "default" theory, because the number of alternative things one

might be doing instead of watching television varies pretty much inversely to the way that television viewing patterns do. (That means that people seem to watch television most when the whether is inclement, when it is a weeknight without weekend activities available, and so on.) The observations are less consistent with the "needs and gratifications" approach, because needs and gratifications ought to be pretty much the same regardless of what day of the week or season of the year it is. Overall, the observations seem to support the "default" theory and contradict the "needs and gratifications" theory.

Scientists virtually never overthrow one theory in favor of another on the basis of a single study or a single set of observations. So, many scientists will still consider the needs and gratifications theory a possible contender, but this discussion does show how theories are tested. Because theories are hypotheses about how certain observations ought to "go together," it is possible

with any consistent theory to make specific predictions about what kinds of observations will turn up under certain circumstances. When these circumstances either turn up or are artificially created in an experiment, it is possible to check the observations actually made with those the theory predicted should happen. The theory is tested by examining how closely the observations actually made agree with those the theory predicted would be made.

While the process of testing a theory or theories is something that goes on for a long time, and many steps are done at once, it may be useful to outline a "typical" set of steps. First, observations accumulate until a specific question or problem reveals itself: in this case, the question is, "what controls television viewing?" Second, hypotheses are derived from whatever theory is available to guide investigations. Third, observations required by the hypotheses are either gathered from existing public observations, or new observations are

made. If standard, public methods for observing the needed variables are not available, new methods must be developed, related to existing observations and methods, and made public. Fourth, the observations are compared with the observations the theory predicted would be made. The difference between what the theory predicts the observations should be and the actual values of the observations gives the degree to which the theory is in error.

The observations are then repeated by others, and their results are checked against the original results. This process of replication may go on many times if the theory is important enough. If the theory works well enough to be useful, efforts are then made to generalize the theory by extending it to other topics and areas. Each of these extensions and generalizations must themselves be replicated, sometimes again and again in the case of an important theory.

In testing a theory, there are four possible

outcomes. The first is that the theory is rejected. In practice, theories are rarely rejected, and, in fact, even after being replaced by a better theory, sometimes they continue to be used anyway if they are easier to use and not too inaccurate. Thus, for example, for most practical purposes, Newton's theory is still used for most everyday calculations, because the Theory of Relativity is somewhat more complicated computationally, and the differences between the observations predicted by both theories are negligible in many practical circumstances.

The second possibility is that the theory is simply left as it was before the observations were undertaken. This is probably the least useful result possible, because no improvement in our ability to understand or predict or control our experiences results from this outcome.

A third possibility is that the theory is generalized to cover more observations than it originally considered. This is a very useful development, and one

scientists eagerly seek.

A fourth possibility is that the theory is modified to make it more accurate; that is, to make the predictions it makes more closely approximate the observations actually made. It is important to remember that a theory is not rejected simply because it is "false:" that is, because the observations it predicts differ from those actually made. No theory is perfectly accurate in all circumstances. Rather a theory is only rejected if a better, more accurate, or more general theory is available to replace it. While an inaccurate theory is not too good, no theory at all is the worst situation possible.

Experiments

Any useful theory makes some predictions or *hypotheses* about what observations are likely to be made under certain circumstances. In some sciences, and for some topics, it is possible to create these special

circumstances artificially. One theory in Communication, for example, predicts that the opinion any person will take toward any object will be the average or mean of all the information he or she has received about that object. It is possible for this topic to create artificially the circumstances in which it can be tested. One can bring people to a laboratory, for example, and introduce to them a new object they have never heard of before, and present them with a quantity of information about that object. You might, for example, give your experimental subjects a written paragraph that said something like this:

> Company A is introducing a new product this year, and is trying to determine its sale price. Five experts were asked, and each of them had a slightly different suggestion. One said it might be worth about $1.75; another suggested $2.39, a

third said $1.49, the fourth said $1.89, and the fifth suggested $1.99.

Later you could ask these people for their own suggestion about how much the new product ought to be worth. The theory predicts that, on the average, the people who read the paragraph would believe the product should be worth the average or mean of these five figures, or $1.90. To the extent that the actual observed average values came out close to that number, the theory would be accurate.

When the circumstances under which the theory makes some prediction can be artificially created (or "manipulated," as some researchers like to say), the study is usually called an "experiment," and sciences in which important factors or variables can be manipulated are frequently called "experimental sciences." In other sciences, however, experiments are sometimes not possible. In astronomy, some theories make predictions

that are beyond human control. Einstein's theory of relativity, for example, predicts that the orbit of the planet Mercury will be slightly different than Newton's theory predicts. There is no way that astronomers can artificially change any of these orbits, so they must simply carry out observations when the right circumstances happen to come up. Sometimes these sciences are called "observational sciences." (But some scientists use the word "experiment" more loosely, and refer to any observations at all as "experiments.")

Some sciences, particularly those that deal with human beings, have a special difficulty: it may, in some cases, be possible to conduct experiments, but unethical. Demographers (scientists who study the characteristics of populations of people) often make hypotheses about how people migrate physically from place to place, or how they move socially, such as from job to job or from one educational level to another. In theory, it is possible to change some of the circumstances of people

artificially to see if this changes they way they migrate, or influences the level of education they attain, and so on, but for ethical reasons such experiments may be inappropriate.

Whatever the special circumstances from science to science or from topic to topic, the process by which theories are tested remains the same and is basically simple: From the theory, special hypotheses are deduced as to what kinds of observations are expected to be made under specific circumstances. These circumstances are then either artificially created in an experiment, or found in nature, and actual observations are made.[8]

The actual observations are then compared with the predicted observations, and the difference between the predicted and actual observations gives the degree of

[8] It may also be that appropriate observations have already been made, and it is only necessary in that case to look them up. This was the case with Newton's theory as well as with the television theories discussed earlier.

error of the theory. While actual experiments and observations conducted by scientists can frequently be extraordinarily difficult and complicated, the fundamental method is always simple.

Science as a Collective Adventure

As we have seen, science is a process that produces an ever growing body of increasingly precise public observations, along with abstract theories that explain more and more of those observations with increasing accuracy. Within this process, each individual scientist, even scientists of the stature of Galileo and Newton, plays only a small role. Science is a collective social process, the product of many scientists organized into universities, research laboratories, scientific societies, and other formal and informal organizations. It is not necessary for any single scientist, or for any single research project, to do all the things that make

science what it is. A single scientist, such as Tycho Brahe, for example, might invent new ways to measure and make precise, concrete observations and record them, without making any abstractions or developing any theory at all. Another scientist, like Newton or Einstein, might seldom or never make any observations at all, but work only on developing abstract theory from the observations of others. Still others, like Galileo, might, at one time or another, develop new methods of observing, perform observations and develop theories. Still others might be involved exclusively in testing theories.

The process of making observations about any given topic, formulating theories and testing them often takes many generations, and in fact is never finished. No matter how much observation and testing has gone into a theory, and no matter how successfully it has worked in the past, science never believes it has found the final answer. The most basic principle of all science is

uncertainty; one must always hold it possible that new observations will crop up that render the best of theories obsolete, and that force us to revise even our most fundamental thinking. When scientists become certain, they become useless.

Summary

Science is only one way of studying communication processes. The goal of communication science is to create a shared, public understanding of communication. It tries to develop a common, shared reference frame, which consists of public, shared methods of observing, so that observations are independent of the observer. Within this shared common reference frame, it attempts to develop general, abstract understandings of how the observations we make are related to each other. These general, abstract understandings are called "theories."

II Science and Communication

Theories must be tested by comparing the observations they predict will occur under certain circumstances with the public observations actually made under those circumstances. When the predictions of theory fail to match observations, they are either rejected or modified to make them more accurate. When they are relatively successful, scientists try to make them more general, so that they apply to more and more observations.