CHAPTER 3
Science, Pseudoscience and the Law

Confidential Correspondence

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I. INTRODUCTION

Chapter 3: Science, Pseudoscience and the Law

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Chapter 3.1: A Test for Science: Science v. Pseudoscience in the Courtroom

“Smart people, like smart lawyers, can come up with very good explanations for mistaken points of view” - Richard P. Feynman (1918-1988)

Learning Goals and Objectives

All legal systems are based upon good evidence and scientific practice. In this chapter, you will need to understand the following concepts:

- What is science;
- What is the scientific method;
- How does the scientific method apply to forensic investigations;
- What is meant by pseudoscience and how can it be identified;
- What is meant by circumstantial evidence and what are its limitations;
- What is meant by probability and statistics;
- How are the probability of events be determined;
- How are ethics important in forensic science

Introduction

Good science can bring amazing insights to legal proceedings while misleading, incorrect, and flawed “science” can easily cause overwhelming problems to a system of criminal justice. The entire foundation of any just legal system rests upon proper evidence supported by the highest level of scientific inquiry and information. When arguments are built upon a poor or incorrect scientific framework, the entire system fails. One of the greatest problems that the courts face, therefore, is determining what evidence and testimony are based upon good, accepted scientific practice and what are not. In this chapter, we will explore some of the basic hallmarks of good science and how to test whether new methods and analysis meet acceptable levels of scientific standards.

In previous chapters, we examined the legal underpinning of forensic evidence, analysis, and testimony in courts. Two of the most important cases in US trial law, the Frye and Daubert cases, focused directly upon the problem of differentiating good science from “junk” science. Prior to the Frye decision in 1923, each local court could decide almost arbitrarily what they would allow in as scientific testimony. Juries, with often limited scientific backgrounds, were forced to decide for themselves what constituted good science with very little guidance. Needless to say, real problems resulted from their inability to identify false science and resulted in juries often simply believing the “scientific” evidence of witnesses who...
presented their case with more skill and enthusiasm rather than on evaluating the actual merits of the science. After the Frye case, however, the courts had for the first time a set of legal guidelines by which they could measure any scientific analysis to see if it met the standards of generally accepted practice. Later cases, such as Daubert, Kumho and others, helped to refine these benchmarks for admissible practice, but the issue of what is good science remains hotly contested today in courtrooms across the world, leaving juries, judges, lawyers and investigators with the continuing need to understand for themselves what constitutes good, valid scientific practice and how to present it effectively to juries. Increasingly, courts are called upon to deal effectively with progressively more complex technological issues that enormously impact criminal justice. To sort all of this out and provide a strong system of justice, we need to understand the basics of what constitutes good science.

What is Science?

Our understanding of science today hinges upon the logical interpretation of systematic observations and experiments. Science is, however, both the collective total of our knowledge and understanding and a process for discovering new things and refining the picture of our physical world. In fact, the word science derives from the Latin word “scientia” meaning knowledge. Today, while our knowledge of important scientific concepts continues to rapidly evolve, the basic approach to understanding these scientific advances remains rooted in critical thinking, analytical problem-solving skills, and the scientific method – all essential components of modern forensic science.

Science seeks also to understand the relationships between things through careful observation, experimentation, and logical analysis. When one action happens, we want to know how that causes another to occur. Similarly, we often want to understand how one property of a material affects other properties of the material. Science tries to understand at a deep level how things work and what causes them to behave in a particular way under a given set of conditions. Science reasons only with the physical world, however, dealing exclusively with phenomena that can be perceived, observed, tested, and validated.

When considering the nature of science, it is important to distinguish between the tools of science and science itself. The tools of science include, among others, mathematics, measurement systems, scientific instrumentation, as well as names and...

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**Figure 3.1.2.** Science tries to understand the physical world in reliable, reproducible, and non-arbitrary terms

(www.sigmaxi.org/resources/merchandise/harris.descriptions.shtml)

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**An Interesting Story…**

A carpenter, a school teacher, and scientist were traveling by train through Scotland when they saw a black sheep through the window of the train. "Aha," said the carpenter with a smile, "I see that Scottish sheep are black." "Hmm," said the school teacher, "You mean that some Scottish sheep are black." "No," said the scientist, "All we know is that there is at least one sheep in Scotland, and that at least one side of that one sheep is black." (anon.)
definitions for various things. These tools are important for our exploration and communication of science but they are really not part of science itself. As the Nobel Prize-winning physicist Richard Feynman illustrated “It is not science to know how to change Centigrade to Fahrenheit. It's necessary, but it is not exactly science. In the same sense, if you were discussing what art is, you wouldn't say art is the knowledge of the fact that a 3-B pencil is softer than a 2-H pencil. It's a distinct difference.” Being able to identify a particular organ as something called a liver really does not tell us anything about the structure, function, and interrelationships it has with other body parts. Names change in different languages but an understanding of how something works is universal. The name is the tool, the understanding is the science.

Science is not able to prove anything beyond simple facts so that our understanding of science is perpetually in a state of change and refinement. This may seem a strange statement – what about gravity, relativity, and similar scientific “laws”, aren’t they proven? As we’ll see in our consideration of the scientific method, these are examples of scientific ideas that have been tested over and over without finding an exception to their predictions. We, therefore, place a great deal of trust in these ideas as being correct, but they have not be proven, just never found wrong. These are two quite different things. Science can, however, readily disprove events and theories. Scientists, including forensic scientists and investigators, must be willing to abandon or modify previously accepted hypotheses and conclusions when faced with new and contradictory data. In addition, scientists must open their experimental findings and analyses up to the scrutiny of others in the much larger scientific community to validate and build upon their work.

Courts and scientists have many things in common, but one important commonality is that when faced with a claim that is asserted to be true, they both seek evidence and validation to support that claim. In a legal context, the US Supreme Court in the Daubert case defined science as “a process for proposing and refining theoretical explanations about the world that are subject to further testing and refinement” and that all “proposed [legal] testimony must be supported by appropriate validation.” This clearly holds the science presented in courts to the highest attainable levels of scientific practice and rigor.

The Scientific Method

We are all born with an intuitive “built-in” form of the scientific method: we observe, seek patterns, experiment, and observe again until we can move beyond simply collecting facts to be able to better predict the consequences of our actions. As we continue to grow and develop, our wealth of observations, recognized patterns, and personal “experiments” provide a rich basis for shaping our perception of the world around us and dictating how we interact with it. We also continually make ever more refined “guesses” and predictions based upon our evolving ideas and then test these predictions through personal interactions with our environment. Science, defined as the systematic knowledge of the physical world gained through observation and experimentation, is quite clearly intimately relevant to all that we see and do as humans. and the scientific method models our own personal growth and development process in many ways.

Figure 3.1.3. A schematic flowchart showing the key steps of the scientific method (newenergytimes.com/v2/reports/TheScientificMethod.shtml).
The scientific method may be defined as the process by which scientists more formally try to construct an accurate understanding of the things and events around us in reliable, reproducible and non-arbitrary terms. The scientific method, therefore, aims to use unbiased methods and logical analyses in order to provide these rational interpretations and new forms of knowledge. It is the way that we conduct scientific work and understanding this process can clearly be used to help identify valid science from false or pseudoscience.

The scientific method is comprised of five key steps: observation, hypothesis formulation, predictions based upon the hypothesis, experimentation, and analysis of the results to support, refine or refute the original hypothesis. These steps are shown schematically in Figure 3.1.3. It all begins, however, with careful observations, measurements, and descriptions.

**Step One: Observations.**
Observation and measurement are rooted in a need to first describe and quantify an object or phenomenon. Lord Kelvin put it well when he said, “When you can measure what you are speaking about, and express it in numbers, you know something about it; but when you cannot measure it, when you cannot express it in numbers, your knowledge of it is of a meager and unsatisfactory kind.” Observations and measurements are both the starting point and the means forward in any scientific inquiry, including forensic investigations. The methods for measurement and the descriptive vocabulary used in this step are largely established through the standard practices of the relevant scientific community. In Chapter 4, we will examine more closely these tools and practices of measurement and description as they specifically relate to forensic science.

**Step Two: Hypothesis.** Once the initial set of observations and measurements has been made, we try to piece them together into a reasonable hypothesis that includes all of the available data. A hypothesis is simply a rough statement or explanation made on the basis of the limited data available and serves as a good starting point of further investigation – an informed first guess. For example, you might hypothesize that a lamp does not light because the light bulb is faulty. This would lead you to a round of experimentation: checking and replacing the bulb, checking to see if the lamp’s plugged in and the switch is on.

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### Three Historic Quotes on Aspects of the Scientific Method for Forensic Scientists

- “The strength of a science is that its conclusions are derived by logical arguments from facts that result from well-designed experiments.” Bruce Mahan (from *University Chemistry*).
- “It is the credo of free men - the opportunity to try, the privilege to err, the courage to experiment anew...experiment, experiment, ever experiment” Roger Bacon (1214 - 1294).
- “Je veux parler des faits” – “Do not rely upon speculation but build upon facts.” Antoine Lavoisier (1743 - 1794).
- “When you have eliminated the impossible, whatever remains, however improbable, must be the truth” Arthur Conan Doyle’s famous fictional detective Sherlock Holmes (*The Sign of the Four*, ch. 6, 1890).
- “He who loves practice without theory is like the sailor who boards ship without a rudder and compass and never knows where he may cast.” Leonardo da Vinci quotes (1452-1519)

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### Abandoned Hypotheses

Science is filled with examples, large and small, of hypotheses that have had to be abandoned in light of new and compelling data, including:

- The flat world concept;
- The Earth centered Universe;
- The ability to magically transmute earth into precious metals;
- Nuclear cold-fusion;
- Smoking cigarettes is safe.
turned on, examining the power cable to see if it’s damaged, and other similar “experiments”. The major role of an hypothesis is to provide a logical starting framework to suggest new experiments and observations that would allow you to test and refine your explanation.

One common error is to regard the hypothesis as an explanation that does not require further testing. No matter how much “sense” an hypothesis makes, it still must be validated and tested.

**Step Three: Prediction.** Once a reasonable hypothesis has been formulated, it should suggest ways to test its validity. More complex problems often require a detailed experimental plan that serves to both set boundaries around the question to be studied as well as to provide information about the soundness of the hypothesis itself. A well-formulated experimental plan will provide the key information needed to evaluate the accuracy and predictive power of the original hypothesis. For example, we might predict that by changing the light bulb, the lamp will function again. A set of logical, reasonable experiments that bear directly upon the central points of the hypothesis are required – is the bulb broken, is the lamp plugged in, etc. Putting your fingers directly into the electrical outlet or checking on solar flare activity would not be good starting places for your investigation of the faulty lamp.

Some types of hypotheses, however, are difficult to use predictively and to test directly. Historical events or criminal actions are often unique, one-time occurrences and cannot be directly experimentally observed, tested, or validated. According to Locard, however, these events do leave behind traces that can be scientifically tested to see if they support the hypothesis for the crime. We can also use scientific methods to understand the range of possibilities that exist under a given set of conditions to support or refute a proposed chain of events.

**Step Four: Experimentation.** The experiments designed to test the hypothesis must be made using the best standard practices available. Any interpretation of an experimental outcome can only be as good as the experimental data itself. Ideally, a series of experiments should be performed using a variety of different techniques to avoid systematic and random errors (see Chapter four). It is relatively easy for inadvertent bias to enter into experiments, often without it being recognized. This bias can be minimized by both recognizing the potential sources of bias and through the process of having the experiments repeated by other scientists who presumably would not have the same set biases as the original experimenter.

A common mistake in experimentation is to eliminate data that does not fit the hypothesis being tested. It is important that all data be handled in the same fashion, regardless of whether they support or refute the hypothesis.
hypothesis. Statistical and other methods exist for determining if some data are caused by systematic measurement errors and can be justifiably eliminated from further analysis – but these tests must be used to scrutinize all data, even those that support the hypothesis (see section 3.2). A real problem in forensic science is that an investigator or analyst might have a strong bias or expectation about a particular result. For example, if an officer delivers a DNA sample taken from clothes and a DNA sample taken from the prime suspect to the lab, and then asks the analyst to show that the two came from the same person, it is likely that the analyst psychologically has a strong bias to find data to support the connection between the two, even if it might not justifiably exist. It is often too easy to discard a data point that does not conform to the hypothesis while not applying the same test on the other data that fits into the expectations. The converse is also true, an “imaginary” data point might be seen as real if one looks hard enough at the background signal. For these reason, it is best if the analyst is not informed about any expected outcomes of an experiment before the experiment is completed.

The main idea of testing an hypothesis is actually to try to determine its limitations, seeking to find when it fails. We often learn much more through the failure of an idea than from its successes. Simply seeking confirmatory evidence for an hypothesis without pushing the boundaries of the analysis can readily lead to a false confidence in the hypothesis. For example, if we only ever test the switch in the lamp, ignoring all other parts of the lamp, then we end up with a very imperfect understanding of the lamp’s operation (see “An Elephant of an Experiment” inset box for another example).

Of course, careful and complete notes are required to validate any experiments performed, especially in the forensics application. Analyses and experiments in the highly regulated forensic world must also include following all established laboratory protocols that often involves validation of experimental results in very specific ways. Most forensic laboratories have

An Elephant of an Experiment

A famous story of unknown origin from antiquity relates the fable about the encounters of six blind men with an elephant:

“Six blind men encounter an elephant – although how they knew that it was an elephant the story does not recount. The first touches its trunk and says that an elephant is like a palm tree, another touches its side and says that an elephant is like a rough wall. Another feels its tail and says that an elephant is like a piece of rope. Each comes into contact with a different part of the elephant and is convinced that their own explanation is correct and that the others are wrong. None of them realizes that they are all experiencing just one part of the same elephant and that none of their explanations are complete.” (story taken from www.bethinking.org/stories-illustrations/introduction/the-blind-men-the-elephant-and-the-zoo.htm).

This story has clear relevance to the proper scope and application of the scientific method. Each blind man, after exploring only one particular facet of the elephant, came up with a view of the animal which in reality was very limited and incomplete. If, instead, they had each employed a broader experimental view and shared data, they would have quickly found where their initial hypotheses that the elephant was palm tree, a wall, or a piece of rope” failed, discovered that the elephant was far more complex than any of their original guesses. and recognized the need to revise their hypotheses through more experimentation.

detailed “Standard Operating Procedures” (called SOPs) set up for everything that they do, including all analyses and procedures that conform to rigorous standards that are widely accepted as best-practices in the field. Any analysis must, therefore, be carried out and validated according to these strict SOPs for it to be routinely acceptable to a court.

Step Five: Analysis and Refinement or Abandonment of the Hypothesis. The data from experiments may support the original hypothesis or might dictate a revision or, if the data requires, the complete abandonment of the original hypothesis in favor of a new “starting” hypothesis. In fact, the scientific method requires that an hypothesis be ruled out and abandoned if its predictions are found to be incompatible with the experimental results. If the hypothesis is, however, supported by the data, a new and more refined set of experiments would be designed that would be capable of probing even more deeply into the problem being considered. Through this cyclical process of hypothesis→experimentation→results and analysis→revised hypothesis, an initial hypothesis is continually revised and refined (Figure 3.1.5) to better describe the phenomenon. The more data and experimentation that supports an hypothesis, the more value and credibility that we can give to the explanation have.

When an hypothesis has been tested over and over and found valid in all the circumstances examined, it may take on added importance and is referred to as a scientific theory or law. The terms “theory” or “law” simply mean that the explanation has been extensively tested and generally accepted by a large number of scientists over a long period of time as valid – it does not mean that it has been proven, just that there have been no known exceptions after a very large amount of data has been accumulated and analyzed. Theories remain theories, however, and unproven in the formal sense. For example, the Law of Gravity or the First Law of Thermodynamics (“conservation of energy”) are called laws because we have yet to find an exception to their concepts and predictions. Nonetheless, few people truly doubt the existence of gravity enough as a theory to test it by stepping off of the top of a high cliff. Science places a great deal of credence and trust in these types of refined explanations and any new experiments that seemingly would refute such well-founded theories would be examined with especially intense scrutiny. A new claim for an antigravity device, for instance, would certainly be open to intense investigation before people would declare it a true exception to the law of gravity.

The Scientific Method and Forensic Science:

Figure 3.1.6. Criminal actions are often unique and cannot be directly experimentally observed, but Locard’s Principle tells us that these events leave behind traces that can be scientifically tested to see if they support the hypothesis for the crime (popularmechanics.com).

Famous Examples of Pseudoscience

There are numerous clear examples of pseudoscience in history that have misled and confused with claims of scientific validity. Some of the examples include:

- Reflexology
- Alchemy
- N-rays
- Engram Theory
- Astrology
- Facilitated Communication
- Extrasensory Perception (ESP)
- Telepathy
- Plant Perception.
Any valid forensic investigation must follow the basic principles of the scientific method to be well accepted by both the scientific and legal communities. In criminalistics, we are usually faced with trying to understand what events have led to an observed result: the crime scene. The investigation must begin, as does the scientific method, with the collection of data — observations, measurements, and descriptions. Once sufficient preliminary information has been amassed, the investigative team usually develops one or several possible hypotheses that can be tested by the forensic data and any other available evidence. The forensic data are then used to support, refine or refute a particular hypothesis of a crime, including any witness accounts of the happenings. A refined hypothesis can then suggest new avenues of investigation that continues the cyclical investigative process of hypothesis → observation/analysis → results and analysis → revised hypothesis. One important point, as described above in the scientific method, is that investigators should specifically look for evidence that would refute their hypothesis of the crime in addition to looking for confirmatory evidence — simply looking for confirmatory evidence may overlook important insights that would lead to a complete investigation and a proper criminal conviction.

One major difference between the legal and scientific worlds is that in basic science, the questions examined are open-ended and are continually subject to revision. In the legal system, however, there is usually a definitive end-point — the point at which the jury is presented with the evidence and hypothesis of the crime and where they must render a final judgment quickly. At that point, the investigation is concluded and inquiry is suspended. Another difference is that courts usually want definitive answers, such as “does this item match a standard” or “did this DNA sample found at the scene come from the suspect”. Science, however, can only refute and not prove things. It can, however, say that the DNA sample found at a crime scene is consistent with one taken from a suspect and give an indication of the probability of a random match — such as a 1 in 4 trillion chance of a random match in the general population of the DNA profile found at the crime scene. This information provides a measure of the trust and credibility that we can place on a particular piece of evidence (See section 3.2). It is then up to the judge or jury to decide how much reliance they should place on the evidence.

What is Pseudoscience?

In most respects, the “opposite” of true science is pseudoscience. The term pseudoscience, sometimes also called “junk”, “fringe”, “pop” or “alternative” science, refers to the practice or set of beliefs that are not founded in the basics of the scientific method. The term pseudoscience comes from the Greek words “pseudo” meaning “false” and “scientia” meaning “knowledge” so that pseudoscience can be defined as “false knowledge.” Typically, pseudoscience is based upon absent, biased or faulty observations and does not rely upon direct evidence for support. It is often claimed to be “scientific” in its approach but without making use of the scientific method.

Throughout history, people have made outlandish and unsupported claims of new theories, quack cures, amazing powers, and incredible

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### The Sharp Line of Occam’s Razor

Occam’s Razor, first presented by the English philosopher William of Ockham in the 1400’s, is a theory as to how to decide between two competing hypotheses that arrive at the same result. Sometimes it is summarized by the phrase “when you have two competing theories that make exactly the same predictions, the simpler one is the better.” Einstein, however, modified this to say “Everything should be made as simple as possible, but not simpler.” The “razor” term comes from the idea of “shaving away” assumptions to separate two competing theories. Often, pseudoscientific ideas are surrounded by unfounded and complex assumptions with convoluted arguments, sometimes claiming mutually contradictory things. Occam’s razor has been used to try to separate pseudoscientific ideas and explanations from truly scientific ideas.
technological feats. To a largely non-scientific public and media, these claims have often been believed at face value by unsuspecting audiences, only to be disappointed later when the claims are proven false. These frauds can also greatly damage the reputation of true scientific work in the public’s estimation since pseudoscience masquerades as real science. A recent National Science Foundation (NSF) study reported that the “belief in pseudoscience is widespread” reflecting a basic lack of understanding of how science works.

The real and often vexing problem is how to tell valid science from faulty pseudoscience? Probably the best way, of course, is to know as much as possible about what is the real nature of science itself. Scientists and philosophers are still debating exactly how best to distinguish between science and pseudoscience but many features are well agreed upon. Fundamentally, pseudoscience does not rely upon the evidence-based scientific method of observation, hypothesis, experimentation, analysis, and revision. Pseudoscience relies on trust while science relies on experimental validation and evidence. Generally, some of the “telltale” features of pseudoscience include:

- **Exaggerated or untestable claims**: Pseudoscience tends to present its claims in imprecise and often vague terms that lack measurements or are supported by faulty assumptions. The claims often include convoluted and complicated explanations that manipulate straightforward explanations into complex descriptions that “sound scientific” (see “Occam’s razor” side box). Pseudoscience also often lacks “boundary conditions” – the conditions under which the theory is valid – and claim broad applicability of their ideas. For example, in Figure 3.1.4. “Snake Oil” was once claimed to cure “headache, neuralgia, toothache, earache, backache, swellings, strains, sore chest, swelling of the throat, contracted cords and muscles, stiff joints, wrenches, dislocations, cuts, bruises, all aches and pains, deafness, rheumatism, sciatica” and other ailments – too good to believe, literally.

- **Based upon hearsay**: Pseudoscientific claims are often based upon unverifiable or anecdotal evidence, such as newspaper reports, unreliable witnesses, other earlier pseudoscientific works, or questionable texts. For example, someone might claim that their toothache was cured when they took a dose of snake oil, so the snake oil

**Figure 3.1.7.** The tension between science and pseudoscience (calamitiesofnature.com).

**Figure 3.1.8.** Pseudoscience may be built upon a scientific fact but then distorts or extends the claims to include non-scientific ideas (videocafe.crooksandliars.com).
must have been the cause of the “miracle” cure. They make this claim without doing any controlled experiments to verify this idea. In truth, the snake oil had little or nothing to do with the disappearance of the toothache but it was simply a coincidence that the dose and the disappearance happened “together” – there was no cause and effect linkage (causal relationship). Pseudoscientific “crank” medical cures, without any real validity, may appeal to people who have not been cured by traditional medical treatments – often with significant harmful effects (Figure 3.1.7 and also see chapter 13).

- **Reluctance towards experimentation and reproducibility:** Pseudoscientific works rarely provide sufficient information or detail to allow others to attempt to duplicate and, therefore, verify their work while science is based upon others duplicating the results reported – reproducibility is very important in science. Proponents of these pseudoscientific ideas shun verification studies and claim the failure of attempts at reproducing their results are due to the failure of science. This is in contrast to scientific ideas that are subjected to intense world-wide scrutiny through duplication and refinement by other scientists.

- **Reliance upon confirmatory experiments rather than broad, open testing:** Explorations of pseudoscientific ideas, when actually tested, rely on confirmatory tests that are designed simply to support the tenants of the pseudoscientific idea itself. Often, the goal of pseudoscience is to rationalize popular ideas and strongly held beliefs rather than to look for alternative possibilities and to test these using experimental methods. Science looks especially for places where a proposed theory might fail.

- **Random disregard of some facts or data:** Evidence that conflicts with pseudoscientific ideas are often simply ignored or explained away as opinion or somehow faulty without legitimate reasons, such as would be provided by applying statistical methods to the data.

- **Often tries to fill voids of scientific understanding:** Science does not claim to have all the answers but simply tries to find explanations for the physical world. In areas where science does not yet have explanations, pseudoscience often tries to step in and provide rationalizations. Because science does not understand a particular phenomenon, it does not mean that a scientific reason will not ultimately be found or that somehow the scientific method has failed. One hundred years ago, the role of DNA in heredity was not...
understood while today we have a fairly detailed picture of how DNA functions biologically.

- **Pseudoscience may rely upon a false authority:** Self-proclaimed experts who have little understanding of a particular field may promote a theory that stands in conflict with all that is known in the field but are often believed because of an inherent distrust of established groups – established scientific organizations, universities, scientists, governments, and others. Too often, we see TV movie stars promoting something because they “play one on TV” – people tend to believe them regardless of how unsubstantiated their claims are simply because they sound scientific, are familiar, and appear trustworthy. This is a problem when pseudoscientific forensic “experts” are allowed to promote their own unjustified and untested ideas to a largely unsuspecting jury.

- **Use of new terminology:** Pseudoscience can often gain an air of scientific acceptability through the use of technical-sounding terminology and jargon. The central idea of pseudoscientific jargon and “technobabble” is to impress, confuse and mislead listeners rather than to promote precise communication as is the use of jargon in true science (Figure 3.1.9 and 3.1.11). As an example, explore online the term “turboencabulator” as a famous example of “technobabble” – the use of incomprehensible or meaningless terms to impress, mislead, or confuse an audience.

- **Does not lead to new discoveries or knowledge:** Scientific ideas are continually revised and lead to more experimentation that, in turn, leads to more knowledge and a deeper understanding of the idea. Science is dynamic, continually changing and leads to new insights. Pseudoscientific ideas are static and do not change appreciably over time, largely because contradictory evidence is discarded because it does not conform to the theory is.

Some of the key differences between science and pseudoscience are given in Table 3.1.1. It is important to note that various systems of belief that are built upon divine knowledge or revelation are typically not considered to be pseudoscience since they generally do not claim to be scientific. Science deals only with understanding the physical universe through observation and experimentation and is, therefore, clearly distinguishable from theology. Thus, there is not an inherent conflict between scientific thought and investigation and divine beliefs as long as each is recognized for their origins, methods, and goals.

Pseudoscientific ideas may be presented as a mixture of true scientific ideas and pseudoscientific components in the courtroom. They may have an appearance of truth at the surface while being built upon an incorrect or flawed foundation. The danger is, of course, when
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<tr>
<th>Table 3.1.1</th>
<th><strong>SCIENCE</strong></th>
<th><strong>PSEUDOSCIENCE</strong></th>
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<tbody>
<tr>
<td><strong>Publication</strong></td>
<td>Journals with articles pre-reviewed by experts in the field and subjected to rigorous editorial and experimental control.</td>
<td>General public or topical media outlets in newspapers, magazines, flyers, brochures, and books. Verification not required.</td>
</tr>
<tr>
<td><strong>Reproducibility</strong></td>
<td>Must be reproducible by others to achieve similar results: full details of the entire experimental method required so others can try to duplicate the experiments.</td>
<td>No requirement for reproducible results and few or vague details on the method used are provided – not enough to attempt to duplicate the result without many guesses.</td>
</tr>
<tr>
<td><strong>Claims</strong></td>
<td>Clearly stated and supported by evidence and generally acceptance by the discipline.</td>
<td>Vague, untestable, or unbounded claims presented without experimental backup.</td>
</tr>
<tr>
<td><strong>Support</strong></td>
<td>Evidence-based claims with full transparency of how the idea was tested.</td>
<td>Anecdotal evidence, misleading statistics.</td>
</tr>
<tr>
<td><strong>Revision</strong></td>
<td>Hypotheses are continually being revised, modified or even abandoned as new data is found</td>
<td>Claims and theories are rarely changed from their original introduction.</td>
</tr>
<tr>
<td><strong>Experimental Plan</strong></td>
<td>Experiments are designed to provide both confirmation and to especially probe for failures or limitations of the hypothesis.</td>
<td>Experiments are designed to give only confirmatory evidence.</td>
</tr>
<tr>
<td><strong>Contradictory Evidence</strong></td>
<td>Evidence that contradicts the hypothesis is included when revising or discarding the hypothesis.</td>
<td>Contradictory evidence is often overlooked or cursorily discarded for unjustifiable reasons.</td>
</tr>
<tr>
<td><strong>Future Development</strong></td>
<td>Provides a pathway forward to learn more about a phenomenon or topic – leads to the creation of more understanding and knowledge.</td>
<td>Static, does not provide any further insights into a topic nor move the field forward in understanding.</td>
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Pseudoscientific ideas and practices are accepted into important systems, such as political or legal systems. Pseudoscientific ideas in the courtroom can be very persuasive to lay juries, leading them to rely upon faulty reasoning and input when making their very important decisions. It is the job of forensic scientists, in conjunction with the entire legal system, to insure that this doesn’t happen through rigorous education, precedent, and practice.

**Try This At Home: Is Astrology Science or Pseudoscience?**

In a recent Harris Poll, 31% of Americans said that they believed in astrology – the study of the stars and planets in determining a person’s traits and destiny. To see if astrology is science or pseudoscience, try this test: Use the criteria for a scientific hypothesis given above to examine the basic ideas of astrology and see if they hold up to the rigor required of the scientific method. Then try this experiment: (1) find a recent newspaper with the horoscope and cut out the horoscope descriptions, (2) remove the name sign (e.g., “Libra”, “Aries”, “Cancer”, Capricorn”) from the description so that only the descriptions are left, (3) given these descriptions to a group of people (the more the better) and ask them to identify their horoscopes for that day, (4) compare their selections with their actual birth-month sign. What percentage of people correctly identified their own horoscopes?

When this “experiment” is done with large number of people, typically about 8% of the people correctly identify their descriptions. Since there are 12 signs of the Zodiac, a random chance would be about 1 in 12 chance of a “correct” guess – or about 8%. What does this suggest about the scientific validity of horoscopes in providing people with reliable information about their destinies?
### Table 3.1.2. Relative levels of certainty to legally admissible levels of proof

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<tr>
<th>LEVELS OF CERTAINTY AND LEVELS OF PROOF</th>
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<td>PROOF</td>
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<td>INVESTIGATION</td>
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(Adapted from *Criminal Investigation: A Method for Reconstructing the Past* by Richard H. Ward and James W. Osterburg, 2000, Anderson Publishing (Cincinnati, OH))