

# Observation and Cogitation: How Serendipity Provides the Building Blocks of Scientific Discovery

*M. K. Stoskopf*

## Abstract

The identification of serendipitous findings in field-based animal research is challenging in part because investigators are reluctant to declare a discovery accidental. Investigators recognize that many factors must be considered. For example, the impact of using carefully ordered observational search patterns in ecologic, pathologic, and epidemiologic investigations could result in findings being categorized as "sought" versus "unsought." Team collaborations are common in these types of investigations and have advantages related to the application of multiple paradigms, paradigm mixing, and paradigm shifting. This approach reduces the perception of serendipity. Issues of search image refinement and the codiscovery of sought and unsought discoveries additionally cloud the identification of a truly serendipitous finding. Nevertheless, basic curiosity and observation are necessary precursors to scientific discovery. It should be recognized that serendipitous discoveries are of significant value in the advancement of science and often present the foundation for important intellectual leaps of understanding.

**Key Words:** curiosity; observation; paradigm shift; scientific method; search image

## Introduction

If you ever have the opportunity to choose between smart and lucky, choose lucky." My father gave me more than a few pieces of such advice in my formative years, and some stayed with me better than others. This concept was one that I remembered, although I think he repeated it only occasionally. Perhaps the advice settled so firmly because it provided me with a very useful reply to people who, upon meeting me, comment on how lucky I am. A quick reply of "better lucky than smart" never fails to move the conversation gracefully past this little challenge. Admittedly, the frequency of these encounters decreased when I left a putatively more glamorous life to enter the hallowed halls of academe; however, they still occur.

---

M. K. Stoskopf, D.V.M., Ph.D., Diplomate, American College of Zoological Medicine, is Professor of Wildlife and Aquatic Medicine and Environmental and Molecular Toxicology, Director of the Environmental Medicine Consortium, and Director of Veterinary International Programs, for North Carolina State University, Raleigh, North Carolina.

Without actually knowing what luck is, I willingly admit to a fair share of it in my life and career; however, at the same time, I am convinced that I also worked hard, prepared thoroughly, and made careful choices. Would "serendipity" be a more soothing term than luck when discussing advantages derived from a combination of intellectual preparedness and chance? That question was perhaps my primary motivation for accepting the challenge of writing about serendipity in scientific discovery. My more fundamental motivation, however, was an interest in exploring the relationship between knowledgeable observation and the scientific method. Does the ever-expanding burden of external controls on scientific experimentation and exploration diminish the potential yield of science by limiting the opportunities for serendipitous discovery? What factors potentially mitigate such an impact by optimizing the yield of knowledge from scientific studies?

Despite the complexity of the questions that arose in my mind, the assigned task was actually quite simple—to identify and discuss clear examples of serendipitous discoveries that involved the use of animals in nonlaboratory settings. The challenge should not be overly daunting considering the tremendous advances that have been made over the recent decades in ecology, wildlife and fisheries sciences, and epidemiology. Surely examples would be found in every aspect of field biology. I would simply comb the autobiographical literature and interview colleagues with long experience and success in field investigations, and then I would winnow out the vast number of examples and retain only the most clear and appropriate. This optimism was perhaps fueled by the assumption that I had a reasonable handle on the meaning of the word serendipity.

On closer examination, however, it became clear that the word has a very robust plasticity in common usage. In some ways, it is this plasticity that makes the word so interesting. I was surprised by the temptation posed by wallowing among the diverse interpretations of a word so casually coined—interpretations that the inventor had essentially discarded but that are characterized by an ever-widening niche in the English language. I have discovered a distinct lack of willingness for investigators to have their discoveries and accomplishments categorized as serendipitous. I believe this reluctance is the result in large part of a tendency to consider the word a synonym for luck or perhaps "by accident."

After much discussion, all of the contributors to this issue of *ILAR Journal* agreed that the lack of clear definition in Walpole's letters to Horace Mann introducing the word

and the rather wide range of interpretations presented by different scholarly authorities presented a challenge to the coherence of the collective work we wished to pursue. A unified definition was needed to provide the necessary scaffolding for our own examination of the relationships between serendipity and scientific discovery. From my perspective, it would help me navigate past challenges while interviewing colleagues. Campbell describes this framework in the Introduction to this issue (Campbell 2005), where he presents us with Walpole's original intended meaning—"an ability to apply sagacity to chance observation and thereby find something other than what one was looking for."

With the agreed-upon definition and explanatory material in hand, it seemed that a renewed series of interviews would surely yield useful examples. Yet to my chagrin, the second, even more extensive round of my queries to colleagues yielded no examples. There were, however, more ideas thrown forth, most to be discarded due to the "unsought" requirement in the definition. It seems that for good field biologists, there is no clear delineation of what one is looking for and what would be "other." Perhaps the issue is best summarized by the mystery writer Lawrence Sanders, who writes, "One aspect of serendipity to bear in mind is that you have to be looking for something in order to find something else" (Sanders 2004). When an example was postulated to my colleagues, it rarely took more than a few minutes to rationalize that in the way the observations were made or recorded, it could be argued that the knowledge obtained was sought. Rhetorical as these arguments could be, I was left without the examples I needed.

As Campbell (2005) carefully points out, the relationship between Walpole's intent for the word and the content of the fairy tales from which he invented the word is far from linear. In addition, although I will strive to adhere to our agreed-upon definition of the word, I find the fairy tales themselves to be quite instructive when examining the role of observation in science, and particularly when seeking to apply the term serendipity to the realm of field studies. In the fairy tales, three princes from Serendip (Sri Lanka or formerly Ceylon) travel without clear purpose and successfully extricate themselves from difficulties through successful and frankly creative interpretations of unplanned observations made during their wanderings. It is my tenet that the fairy tales present the case for the following important, and too often neglected, factors that enhance scientific discovery: the importance of observation; the impact of search image on discovery; the value of paradigm shifting and collaboration; and finally, the value of "wandering" or visiting issues with no expected direct application of the exploration (i.e., basic curiosity). These factors are discussed below briefly.

## Observation

The role of observation in science was once accepted as a primary requirement before any experimental efforts could

be considered. Although stated in many ways, the five accepted steps of the scientific method as taught in the 1950s and -60s were to (1) observe and identify the problem, (2) gather information about the problem, (3) formulate an hypothesis that can be tested, (4) gather objective data to test the hypothesis, and (5) interpret the data in regard to the identified problem. It was considered not only bad form but also poor practice to fail to perform the first steps of the method. However, for a long time, there has been a challenging schism in the halls of science between scientists who espouse the value of observation for observation's sake as a necessary precursor to discovery and those who embrace the more restricted philosophies of science that Emanuel Kant set down near the end of the 18th century. Kant, in referring to classic experimental discoveries by Galileo, Torricelli, and Stahl stated, "They learned that reason has insight only into that which reason produces after a plan of its own; that reason must not allow itself to be constrained, as it were, by nature's reins . . ." (Glashow 2002). In Kant's vision of science, "Accidental observations, made in obedience to no previously thought-out plan, can never be made to yield a necessary law, which reason alone is concerned to discover . . ." (Kant 1929/1965). In other words, observation or, as Kant referred to it, "experience" could never provide the evidence needed to prove a principal truth.

As Glashow (2002) points out, Kant's life and work preceded the modern era of science, when so many discoveries have been made through what could be considered serendipity. It is possible that such experience might have moderated Kant's rigid views of scientific inquiry. However, in recent years, a tendency has emerged to focus, knowingly or not, on Kant's obsession with the latter parts of the scientific method—in particular, preparing and testing hypotheses. Instructions for submission of proposals for funding to major federal funding agencies boldly state the requirement for hypotheses in the proposal, apparently assuming that the first two fifths of the method are either of little value or have already been completed before funding is sought. In an apparent effort to be more "scholarly" or "scientific," private foundations, even very small ones, have emulated these requirements with demands for clearly stated hypotheses in proposals. The implications again are that observation, along with problem identification and gathering information, are insufficient reasons for consideration of financial support. One is left to wonder how the three princes would have had the resources to conduct their wanderings if they had been forced to set out the hypotheses they would reach in their travails before starting out on the journey. Truthfully, good scientists continue to find ways to observe and to follow the scientific method despite bureaucratic barriers; however, the relegation of observation to a second-class tier of science does not bode well for the advancement of knowledge.

The issue described above is particularly acute in the arena of biological field studies. Funding for biologists to observe phenomena is difficult to obtain without the firm

promise of testing what might be termed a “pseudohypothesis.” Wise scientists construct these pseudohypotheses because they can test them easily and because the outcomes are relatively predictable. Unfortunately, their very existence can taint the observations made after funding is achieved.

The basic challenge of the subjective nature of even apparently objective observations is addressed by the famous science fiction writer Robert Heinlein in his classic novel *Stranger in a Strange Land* (Heinlein 1961). In support of the premise that there can be an objective truth, Heinlein presents the reader with the concept of the “Fair Witness,” a neutral observer trained to watch events unfold with no preconceived bias as to what should occur, and to remember an unbiased account of the event (Murrell 1988). Central characters of the novel hire these individuals, who use no form of technology to retain detailed memories of important transactions or events. Fair Witnesses are trained never to interfere in any of the situations they are employed to observe, and they are particularly careful not to interpret what they observe. Anne, a Fair Witness employed by one of the central characters, Jubal Harshaw, is asked at one point by Jubal to tell him the color of his own house. Anne replies, “It is white on this side.” Jubal then points out that “It doesn’t occur to Anne to infer the other side is white too.” In Heinlein’s construct of a future society, he posits the important need for unbiased observation, not only in science but also in everyday life.

Although the fairy tales that gave rise to the term serendipity do not address the value of unbiased observations (albeit quite the opposite in some respects), they do treat observation as the prerequisite to deducing or inducing reality. One of the more famous fairy tales includes a narration of the three princes being arrested and brought before the magistrate as suspects in a heinous crime of animal theft (camel, mule, or horse, depending on the translation and version). The princes implicate themselves by successfully predicting that the animal had a bad eye and missing tooth and was lame, based on both remarkable observations and even more remarkable interpretations of the observations. The man whose animal was missing portends that they must have seen it and stolen it to make such an accurate description of the missing animal, and so they are arrested. Only later, when the animal is found still wandering down the road, are they exonerated. The amazing, and in the story correct, deductions are based on the observation by one of the princes that the grass was grazed on only one side of the road and was more lush on the other side, suggesting the lack of vision in the direction of the lush side of the road. A regular pattern of higher blades of grass in patches the size of a camel’s tooth suggested that a tooth was missing, and the pattern of the footprints in the dust suggested the lameness.

One could easily argue that it was the relatively remarkable and detailed observations that caused the princes’ trouble in the first place, although I believe their clever interpretations of the observations are more culpable. All of

the explanations of the observations provided by the tale have multiple alternative explanations, some of which (e.g., Ocam’s Razor) are integrated into a single event. It is not the details of the princes’ interpretation, but rather their observations, that seem to support the use of the word serendipity in the agreed-upon definition of contributors in this *ILAR Journal* issue. It can be argued that the observations made by the princes resulted in unsought knowledge. It is often presupposed, but not made clear in the story, that the observations they made were unplanned or not systematic. But what if they were systematic? What if the princes had a system of observation that led them to view and record all of the details that played roles in their stories? Would their tale have been any less amazing?

To help resolve the foregoing questions, it might be useful to consider the case of pathologists. When these specialists examine a corpse, they do so in a methodical and systematic manner, making and noting observations in an effort to establish the cause of death. The system pertains more to the completeness of observation than to the actual discovery. Similar observation systems are used by ecologists as well as wildlife and fisheries biologists to catalog the complex systems they observe. I would argue that the mere existence of a systematic approach for conducting observations does not preclude a discovery from being serendipitous in and of itself, even though it essentially removes the effort from the “random groping” category disdained by Kant.

The discovery of acid rain exemplifies systematic field observation that has yielded unexpected or unsought results that have later required sagacious interpretation. The discovery of acid rain occurred over time and in different locations. The most frequent attributions, to the English chemist Robert Angus Smith, are undoubtedly reasonable because his reports on the chemical composition of rain in the late 1800s first included the term “acid rain.” However, it is also quite clear that acid rain was discovered at least several times by scientists who were not familiar with Robert Smith’s earlier work, and at least two of these discoveries have been deemed serendipitous by many, including the discoverers themselves. For example, Hub Vogelman, a botanist at the University of Vermont, is given credit for recognizing a problem with the precipitation data he was systematically gathering on Camel’s Hump in Vermont and for connecting the insight to the large numbers of dying and ill spruce trees in the region. Dr. Vogelman was not seeking either the discovery of ill trees or the relationship with acidic precipitation in his research, but he was systematically observing the Camel’s Hump system in a way that facilitated the discoveries.

An additional example involving acid rain involved the Swedish soil scientist Svante Oden. Oden also was not seeking knowledge of acid rain when in the 1960s he systematically examined the causes of losses of fish and marine invertebrates in Scandinavian lakes and tidal regions. His work is pertinent to this discussion because it was based on

observing population changes in animals, rather than plants. Dr. Oden was actively investigating the causes of huge mortality events in Swedish salmon and other fish. His work and that of others had reasonably eliminated differences in soil type as underlying causes of the mortality events. His insight into the possibility that the problem was arising from aerial deposition of acidifiers into the lakes was likely based on many observations; however, he later cited the importance of one observational experiment involving his examination of marine life in tidal pools on the Scandinavian coast. He observed that marine life was quite abundant and diverse in the tide pools that were close to the surf line and therefore were frequently replenished with new water from the sea. As the distance from the low tide surf line increased, the biomass and biodiversity of the pools declined precipitously until pools at the far reaches of the tide held essentially no animal life.

Oden's observation was just that—an observation. The sagacity that he applied to the observation was that these tidal pools could be relevant to the lakes he was studying and could offer a simple model. He postulated that the difference between the pools would be the source of water they received. Pools close to the low tide surf line would be replenished primarily with sea water, and pools farther from the surf line would receive more and more of their water in the form of rain and atmospheric deposition. Measuring the pH of the pools with a simple pH meter provided evidence. Pools fed by ocean waters retained an alkaline pH and significant buffer capacity, whereas pools fed by rain were actually acidic and lacked buffer capacity. It was likely that the observed differences were due to the nature of rain. Additional careful work documented the remote source of the acidifying compounds in rain and stimulated international efforts in regulating air pollution.

The potential difficulty with this example is that ultimately, Dr. Oden did find a potential answer to the question he sought to resolve—the cause of the fish mortalities occurring in his country. What he did not seek but simultaneously discovered was a pollution mechanism with ramifications far beyond the question he was seeking to answer. This deduction would be somewhat analogous to the attribution of a cause of death by a pathologist examining a case. The discovery may involve evidence of a hitherto unknown pathogenesis during a routine necropsy.

So the following questions remain:

- Does a discovery qualify as serendipitous when observers use a systematic approach for their observations? I believe the answer must be yes.
- Is the serendipity of a discovery negated when the searcher also finds a sought answer in the same efforts? I argue that it is not. I believe that the ability of the princes of Serendip to find their way to town (which I interpret as a sought goal) does not negate the nature of their observations and interpretations leading to the description of the wayward camel, horse, or mule.

## Search Image and Paradigm Shifting

Why did the princes observe what they did? Was one a botanist by avocation who was interested in roadside plants, or was another an avid hunter interested in animal tracks? How did they choose what to look at in their wandering journey, and how did they know what it was they saw?

Although serendipity could be interpreted to imply that there should be no search image whatsoever, I disagree with this interpretation, which potentially limits the availability of examples of serendipitous discoveries. Anyone who has had the privilege of going into the field with an experienced birder has witnessed the importance of search image in action. Similar experiences can be enjoyed by joining an experienced paleontologist on a walk through a fossil-strewn landscape. The person with an untrained eye searches and searches, while the experienced person finds fossil after fossil or bird after bird. As one sees more of the fossils or birds, it is possible to begin developing a personal search image, and to experience a slow increase in the number of useful finds. One must know what is sought or, conversely, be able to identify something as unusual before it can be winnowed into the relatively small number of observations that can be considered thoughtfully. In the tale of the one-eyed camel, at least one of the princes had to have the search image of either grazed grass or ungrazed grass to be able to see the difference. Similarly, at least one prince had to have the search image in place for the tracks of a normal-gaited camel, if not for a lame camel.

Together, search image and experience play a very strong role in scientific observation, and one of the true challenges in scientific inquiry is trying to maintain an unbiased point of view as experience increases the rigidity of our search images. I postulate that the combination of experience and search image plays a major role in field scientists declining to consider their discoveries as serendipitous, when in truth they may fit that description. Knowing what to look for is not always synonymous with seeking. When seeking is not involved, very preliminary events may frequently be obscured by subsequent years of refined seeking after an initial discovery has been launched.

I find it quite interesting that there were three princes of Serendip. The details are not entirely clear in the various translations of the fairy tales, but it is obvious that the princes have different interests and personality. The solutions to their adventures are never developed through the sagacity of one prince alone; each prince adds to the knowledge that drives the tale. This narration process relates to paradigm shifting, which is an important tool in major scientific discoveries. All sagacity is not necessarily equal in value. As search images become more rigid, it can become very difficult, if not impossible, to understand the subtle details of an observation that would steer someone to original alternative interpretations of what has been observed. Thus, young graduate students who have yet to accept completely the extant dogma of the discipline they seek to pursue can be very valuable observers. The simple expedient of

inviting “fresh eyes” to look at a problem has a long history in scientific discovery, and the impact is perhaps accentuated when those fresh eyes do not share the same experience and training as the original investigator.

The multiple discoveries of acid rain would all support the supposition that looking at a problem with a different basis of thought can be beneficial. None of the “discoverers” were meteorologists or limnologists, although Smith was a trained chemist who focused on water. Perhaps a better example regarding the importance of search image and paradigm shifting is described below, in the identification of the emerging epidemic of West Nile virus in the United States, even though it takes place in the center of a large city rather than in deep woods or wilderness.

In the fall of 1999, physicians in New York City were diagnosing a virulent form of encephalitis in several, mostly older patients across the city. Although the number of cases was not excessive; public health measures were deemed warranted after seven deaths and at least 60 hospitalized patients. The cases were being managed under the diagnosis of St. Louis encephalitis, and anti-mosquito spraying programs were activated in Queens, New York, which appeared to be the center of the outbreak. At the same time, Dr. Tracey McNamara, the pathologist for the Wildlife Conservation Society (formerly called the Bronx Zoo), was puzzling over the unexplained deaths of various species of birds both in the zoo collection and from outside the zoo. The deaths were characterized by encephalitis of a viral nature. Although Dr. McNamara was aware of the outbreak of human disease being diagnosed as St. Louis encephalitis, the death of birds had not been associated with St. Louis encephalitis.

The sagacity that accompanied Dr. McNamara’s unsought discovery was her willingness to consider that the cause of the human outbreak might be a different virus from the St. Louis encephalitis virus. This identification would ultimately have huge implications related to the epidemiology of the outbreak. The Centers for Disease Control and Prevention was not particularly interested in a veterinarian’s inquiries or offers of samples; after all, they had a working diagnosis. Fortunately, military and the US Department of Agriculture (USDA<sup>1</sup>) staff were more curious. The geography and timing of the outbreak presented military concerns about potential biological warfare, and the deaths in wild birds posed possible challenges for the poultry industry. Some very detailed and well-conducted research by the specialists at US Army Military Research Institute in Infectious Diseases and the USDA Research Center diagnosed the disease agent in the zoo birds as a flavivirus and eventually as West Nile virus. Later it became clear that this virus was also responsible for the human morbidity and mortality occurring. This discovery was critical to directing the epidemiological investigations and preventative and control programs across the United States as the virus spread rap-

idly and unchecked across the country, affecting more than 200 species of wildlife.

In this example, the search image of the physicians and human health investigators was too limited for them to make the diagnosis on their own. Only through collaboration and utilization of the paradigm shift between human and veterinary pathology was recognition of the true nature of the problem possible. It was serendipitous that a crow died and was taken to the Wildlife Conservation Society. It was also serendipitous that the zoo pathologist connected the link between bird deaths in and around the zoo and the human disease being reported in a small scale throughout her city. The persistence to develop the necessary collaborations and teamwork to answer the question of the relationship between the two outbreaks went far beyond serendipity and is a good example of professional dedication. In addition, underlying everything was a basic curiosity that allowed Dr. McNamara to wonder, “What if?”

## Basic Curiosity

The trait that I value most in my graduate students, colleagues, and collaborators, and even my other personal friends, is a healthy and vigorous intellectual curiosity. This characteristic is roughly translated into the ability to question what is known and to explore what is thought to be unknowable. The willingness to expend neuronal effort on questions that may or may not have any immediate relevance to one’s income illustrates the difference between a technically proficient investigator and a creative and stimulating scientist. The truly great scientists seem to maintain this basic curiosity throughout their lives and to avoid the intellectual sloth that can, and too commonly does, accompany acclaim.

The prominent scientist and science fiction writer Arthur C. Clarke can perhaps be described as serendipitous by virtue of his many years of residence in Sri Lanka. Clarke provides an interesting insight into the challenge of intellectual curiosity: “If an elderly but distinguished scientist says that something is possible, he is almost certainly right, but if he says that it is impossible, he is very probably wrong” (Clarke 1962, p. 14). Restated, the advancement of scientific knowledge is fed by the deep familiarity of studied experts, but it is driven forward in bursts by the curiosity of the minds who can allow themselves the luxury of wandering beyond the known possibilities (Kuhn 1962).

## Concluding Thoughts

The diversity of the observations of the three princes of Serendip in their wandering adventures is a good indication that they were extremely curious. Although not recorded in the fairy tales, it seems likely that the princes observed many things that were not directly related to their extrication from particular misadventures. It is also consistent with

<sup>1</sup>Abbreviation used in this article: USDA, US Department of Agriculture.

the narrated details to infer that they applied sagacity to questions that arose from the observations. What made the fairy tales so popular as to be reprinted in translations multiple times, centuries after their first publication, is the delight readers have found in the unexpected answers the princes provided to what seemed like such “normal” questions. Accordingly, it is crucial to the advancement of science to reward and encourage intellectual curiosity and individuals’ willingness to explore and re-explore questions with no known practical application. Serendipity demands curiosity. Indeed, the future of science would be at risk of losing its vigor if we fail to embrace the following, valuable aspects of the scientific method:

- Observation is a necessary precursor to scientific discovery.
- Respect for the intellectual victory that occurs each time a serendipitous discovery is made is a critical component of scientific discovery. It must be recognized that serendipitous discoveries are at the very least equal to

the value of discoveries made through carefully planned incremental experimentation.

## References

- Block L. 2004. Publications of Lawrence Block. Available online (<http://findability.org/topics/misc.php>).
- Campbell WC. 2005. Serendipity in research involving laboratory animals. *ILAR J* 46:329-331.
- Clarke AC. 1962. Profiles of the Future: An Inquiry into the Limits of the Possible. New York: Harper & Row. p 14.
- Kant I. 1929/1965. Critique of Pure Reason (Smith NK, Transl). (Unabridged). New York: St. Martin’s Press.
- Heinlein R. 1961. Stranger in a Strange Land. New York: G.P. Putnam’s Sons.
- Glashow SL. 2002. Immanuel Kant versus the Princes of Serendip: Does science evolve through blind chance or intelligent design? *Contrib Sci* 2:252-255 Barcelona: Institut d’Estudis Catalans.
- Kuhn TS. 1962. The Structure of Scientific Revolutions. Chicago: University of Chicago Press.
- Murrell TR. 1988. Romance Meets Reality in Three Novels of Robert Heinlein. Masters Thesis. Columbus: The Ohio State University.