# “Multiple Discovery.”

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## Abstract

Multiple discovery is technically defined as when two or more scientists or inventors independently and often simultaneously give expression to a similar theory, form, model, or invention. The concept is intended to convey that scientists operate within a community and that their discoveries are fostered through an ongoing exchange and communication process; thus, discovery is defined in contextual (rather than exceptional) terms. Parallel discoveries are defined as those that are independent of one another and simultaneous in time. Parallels are considered multiples in this article and the two terms are used interchangeably.

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## Keywords

Creativity, Discovery, Eponymy, Innovation, Invention, Matthew Effect, Multiple Discovery, Pluralism, Singleton, Zeitgeist,

## Glossary

*Camera obscura:* A *camera obscura* is a darkened space with a small opening admitting light through a mirror and lens arrangement. This set-up projects an image of the outside world onto a viewing table or plate.

*Camera lucida:* A *camera lucida* is a small hand-held, four-sided prism used to facilitate accurate sketching of objects in broad daylight.

Eponymy: The practice of affixing personal names to all or a part of what someone has invented, discovered, or supported (e. g., Euclidean geometry, daguerreotype, Planck’s constant, Boyle’s Law).

Matthew Effect: A complex pattern of giving greater increments of recognition to scientists of considerable repute while withholding such recognition from those who have not yet made their mark. Derived from a verse in the biblical Gospel of Matthew (25:29) that reads: “Unto every one that hath shall be given, and he shall have abundance: but from him that hath not shall be taken away even that which he hath."

Parallel discoveries: Independent and similar discoveries. A synonym for multiple discoveries or "multiples."

Pluralism: Grants a kind of equivalence to many possibilities, making them seem more or less equal.

Problem-finding: The recognition, identification, and definition of an anomaly, obstacle, or problem that must be resolved in order for problem-solving to begin.

Singleton: Something only invented or discovered once.

Zeitgeist: Spirit of the times. The actual spirit of a Zeitgeist can only be understood in a long retrospect.

**Body text**

## I. OVERVIEW

Multiple Discovery is the technical concept used to explain the difficulty in assigning independent priority when two or more scientists or inventors give expression to a similar theory, form, model, or invention. An incomplete list would include: (1) the independent invention of the differential and integral calculus by Isaac Newton and Gottfried Wilhelm Leibniz; (2) the discovery of the light bulb by both Sir Joseph Wilson Swann and Thomas Edison; (3) the independent discovery of the fundamental principle of analytic geometry by Pierre de Fermat and René Descartes; (4) the discovery of Neptune, generally credited to the British mathematician John Couch Adams as well as Urbain-Jean-Joseph Le Verrier of France; (5) the non-Euclidean geometries independently discovered by Nikolai Ivanovich Lobachevsky, Janos Bolyai, Karl Friedrich Gauss, and George Friedrich Bernhard Riemann; (6) the discovery of anaesthesia in the 19th century attributed to Crawford Long, Horace Wells, William Thomas Green Morton, Charles Jackson, and others; and (7) the controversial discovery of single-wall carbon nanotubes and methods to produce them using transition-metal catalysts generally attributed to groups led by Donald S. Bethune at IBM and Sumio Iijima at NEC in the 1990s despite evidence showing that Russian researchers had independently reported this discovery in the 1950s.

This article introduces case studies that demonstrate multiple discovery in action and analyzes the difficulty in attributing discovery to a particular individual or group. The text also examines cases that show not all discoveries are easily fit into the multiple discovery framework. This first section provides an overview of multiple discovery as a concept. Contextual issues related to scientific institutional practices, values, and unexpected discoveries are presented in section II. Section III explores the relationship between the individual and the community, focusing primarily on examples combining science and the visual arts. The final section integrates multiple discovery with cultural, philosophical and educational issues.

Overall, multiple discovery entered the science studies lexicon as a term to convey that scientists work within a community and that this community, by definition, is a domain where several people are using similar methods and technologies in exploring problems of scientific interest. Arguments favoring multiple discovery are based on the evidence that shared ideas and shared instruments are an integral part of each individual scientist's biography and that many discoveries share patterns of similarity. Moreover, it is argued, the extensive number of parallel discoveries that have been documented support the idea that something critical is lost when discovery is simply reduced to psychological thoughts and subjective processes within the heads of creative individuals. As a contextual idea, multiple discovery is also broadly defined so as to include the auxiliary products that are often needed for a discovery to be practical. For example, the invention of the telephone — be it attributed to Elisha Gray, Alexander Graham Bell, or both — necessitated the invention of switching devices, amplifiers, transformers, and transmission mechanisms.

Critics of the multiple discovery characterization say that conceiving of scientific innovation simply in terms of community exchange pushes aside many unresolved issues in regard to what creativity actually is and the actual body of knowledge we bring to our work. Moreover, when we look closely at particular discoveries we find that some fit into the multiple framework more easily than others. These unresolved areas, the critics add, include the "art" of science, the evidence that chance only favors the prepared mind, and the particular kinds of education, focus, and passion creative individuals bring to their work. In addition, the multiples characterization does not account for those inventions or discoveries that are only discovered once (termed singletons). Similarly, the multiple discovery designation does not address why one individual makes exceptional multiple contributions. For example, recognized as one of the most creative people ever to have lived, Albert Einstein revolutionized scientific and philosophic inquiry in the twentieth century. His reputation was largely a result of work done during his *annus mirabilis* (1905), when he published five papers that laid the groundwork for shattering cherished scientific beliefs.

An unusual individual like Albert Einstein, who opened more than one door in his field, offers a good touchstone for conceptualizing the amorphous quality of multiple discovery discussions. First, this kind of exceptional work raises the question of whether the high points of one individual's achievement and the comprehensive nature of an individual's contributions can be fully addressed using a model highlighting communal influences. In Einstein's case, multiple discovery theorists argue that all of Einstein's discoveries would have happened even without an Einstein. From this perspective, the discoveries may have taken more time, and required more minds, but the climate was ripe for these problems to be solved and thus they would have been solved. Critics of this position say the multiple discovery argument does not actually explain why Einstein was able to conceptualize so many ideas that were not yet directly a part of his culture and transform the theoretical physics in a way that extended beyond physics and into the culture-at-large as well.

## II. SCIENTIFIC ISSUES AND HISTORICAL EXAMPLES

### A. Institutional practices and values

Twenty-first century discussions of multiple discovery continue to rely heavily on the ideas of sociologists, anthropologists, and historians of science of the twentieth century (e.g., William F.

Ogburn and Dorothy S. Thomas, Robert K. Merton and Elinor G. Barber, Alfred L. Kroeber, and George Sarton). These earlier researchers catalogued a vast number of discoveries that emphasized the role of context (rather than a particular person/genius), institutional practices, and values. These have been characterized as multiples since Merton. Merton's idea of the "Matthew effect," presented in the 1960s, has also had a significant impact on the debates. According to *Matthew* (25:29) "Unto every one that hath shall be given, and he shall have abundance: but from him that hath not shall be taken away even that which he hath." Merton's point here was that whether the discovery is recognized through the commemorative use of eponymy or simply results in better funding, those who are credited with priority are elevated to influential positions and thus have the leverage to disproportionately increase their stature on an ongoing basis. This view contrasts with Donald Campbell's argument that credit for multiples often goes to more obscure scientists because the latter have more eponymic value. Scientists who make lots of discoveries dilute the value of their name for this purpose.

The ideal of science has always included a picture of dedicated individuals working toward human good and the presupposition that humility is a part of a cooperative effort to reveal (and apply) universals. Yet, and despite the value placed on humility in scientific practice, proof of personal accomplishment is a critical component in gaining professional employment, prestige, promotion, and funding. Thus, the ideal is often contrasted with a reality that points to scientists working for the rewards associated with professional recognition within the institutional system, a view that suggests that humility and ideals do not fully explain scientific practices and values. More recently, researchers have probed cultural factors more systemically in an effort to ferret out how we develop expertise and how different family backgrounds influence performance and creativity. One particularly fertile idea is Malcolm Gladwell's outlier. An outlier is situated away from or classed differently from a main or related body. Using the outlier concept to expand on Merton's idea of "accumulative advantage," Gladwell suggests that family background, access to tools and training, and the time in which one is born plays a role in the development of (multiple and individual) creative contributions.

All in all, the evidence supporting background, training and position does not resolve many of the anomalies associated with multiple discoveries. With multiple discoveries in a particular geographic area (*e.g.,* the West), priority is often disputed, many of the disputes involve values, and many of the disputes are acrimonious, long-standing, and aggressively pursued. For example, the controversy between Newton and Leibniz over the invention of the calculus is one of the best known examples of a priority dispute involving parallel discoveries. It did not involve an esteemed individual and one on the margins of science. Rather, the dispute involved two individuals of high repute. This example shows how hard-fought some priority battles are. Although Leibniz published first, Newton developed his version of the calculus several years earlier. While it is now generally agreed that the two systems use different approaches and were developed independently, at the time each man accused the other of plagiarism. It was an emotional disagreement, to put it mildly. When Newton became the President of the Royal Society he decided to appoint a committee to adjudicate the rival claims of Leibniz and himself on the matter of priority. Historical records reveal Newton packed the committee, directed its activities, and wrote many of the published reports issued by the group. The second report (a draft of which was written in Newton's handwriting) is especially noteworthy because the anonymous author (Newton!) states that: "no one is a proper witness in his own cause."

Given the way the investigation was conducted (by Newton), it is not surprising that the committee voted in favor of Newton.

Other cases reveal that to find efforts to resolve a priority controversy are frequently totally unsuccessful. This was the case with the discovery of anesthesia. Eventually the U.S. Congress was called upon to settle the heated debate that had resulted in an intense bitterness among the four American claimants (Long, Wells, Jackson, and Morton). Even Congress could not decide. The upshot was that the U.S. House of Representatives passed a bill granting Morton credit and money for the invention of anesthesia, but the Senate failed to adopt it. As in many of the cases, the anesthesia controversy had a tremendous impact on the personal lives of those involved. One claimant, Wells, committed suicide in 1848. Another, Jackson, died in an insane asylum in 1880.

This is not to say that multiples are synonymous with animosity and rancor. Moreover, given the “Matthew Effect,” it is also important to note that in some cases the wrangling appears to be oversimplified when characterized as the esteemed as opposed to the marginal. When Charles Darwin received a copy of Alfred Wallace’s theory of evolution he spoke of the striking coincidence to his own theory, actually developed several years before Wallace’s publication. In this case, even Darwin’s chapter headings used Wallace’s terms. This striking coincidence illustrates that regardless of whether one wants to credit Darwin for the theory of natural selection or characterize the insight purely as a multiple discovery and then attribute it to Darwin and Wallace – their work was presented together in a joint paper at the Linnaean Society on July 1, 1858) – does not change the fact that the theories took form at a particular point in time. This ‘coincidence’ has encouraged many to apply the idea of *Zeitgeist* to parallel discoveries and to emphasize that parallels appear to reflect the spirit of a time.

All do not accept *Zeitgeist* correlations as sufficient explanations, however. In terms of the Darwin/Wallace comparison, for instance, we find that there are significant differences in how they conducted their investigations. Darwin studied marine invertebrates while at Edinburgh University and then travelled to the Galapagos Islands, where he began to systematically formulate his theories of natural selection and evolution. Wallace, by contrast, did extensive fieldwork, in the Amazon River basin and in the Malay Archipelago. In weighing the different backgrounds the two men brought to their work one additional factor stands out: some say that was is unlikely that Wallace's views would have been taken seriously without Darwin’s support given that Darwin's social and scientific status was far greater than Wallace's.

*Zeitgeist,* which implies inevitability, also brings additional issues into play. First, if we define discovery in terms of a “spirit of a time” how do we accommodate developmental aspects of discovery? Second, *Zeitgeist* fails to contend with factors that are not a part of a culture per se, such as natural catastrophes and serendipity. Although these kinds of events significantly impact individual ideas as well as the broader community, they do not germinate from within a culture or even from within an individual. Specific concepts proposed to explain (or explain away) *Zeitgeist* in light of the existence of inexplicable events include God, free will, fate, causality, chance, and determinism. Third, there are also concrete, contextual debating points that are often a part of *Zeitgeist* discussion. These turn on the evidence that some individuals within a specific cultural environment will see theoretical and actual possibilities their colleagues miss. In addition, *Zeitgeist* does not adequately address unexpected discoveries; these are the discoveries that happen despite the evidence that no one was working toward solving the problem involved.

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## B. Unexpected discoveries

The crux of the debate surrounding unexpected discoveries in science centers on the question of what drives individual creativity. Why do some *choose to investigate* anomalies in nature and theory that others noticed and did not pursue? In other words, often a scientist chooses to focus on more solvable or socially esteemed problems that reflect the interests of his or her scientific community. Later, with the evidence that an important and unexpected discovery touched upon material he or she had seen and ignored the scientist is likely to acknowledge having seen a facsimile and put it aside. As such, the multiples issue is not just that history books, perhaps in error, tend to refer to discoveries in terms of individuals (e. g., we speak of Halley's Comet, the Copernican Revolution, and Linnaean system). Rather, there is also evidence that a contextually defined focus for discovery can overlook that neither products nor minds are generic --- and the minds of particular individuals have made a difference.

Sir Alexander Fleming's discovery of penicillin and Wilhelm Conrad Röntgen's discovery of x-rays are examples that show that context alone does not account for how an individual's attentive focus on an anomaly can lead to an extraordinary discovery. In Fleming's case, for instance, in 1928 he noticed a bacteria-free circle in a petri dish had been spoiled by a mold that killed the bacteria. Investigating, he found a substance in the mold that prevented growth of the bacteria and he termed it penicillin. Historical records indicate that similar observations had been made fifty years earlier, the primary difference between the earlier work and Fleming's is that only Fleming's work led to the discovery of antibiotics.

Röntgen , on the other hand, discovered X-rays in 1895 when he found that invisible radiation could not only penetrate solid, opaque substances but was also capable of producing images of the interiors. His investigation began only after Röntgen observed his bones were visible on a photographic plate during one of his experiments. At this time, Röntgen was working with cathode rays and a variation of a Crookes tube designed by a younger colleague, Philipp Lenard (who later demanded credit for the discovery). After Röntgen investigated the anomaly, he deduced that the rays created the image of his bones, which were easily discernable through his skin due to the different qualities of bones and flesh. The critical point here is that many scientists were working with Crookes tube and cathode rays at this time. For example, A. W. Godspeed of the University of Pennsylvania and a friend W. J. Jennings had made similar pictures six years earlier and filed them away. In addition, Crookes, the inventor of the tube, had observed that photographic plates fogged when placed near a Crookes tube. The evidence of these earlier observations has encouraged some to argue that the discovery of X-rays was inevitable and thus a multiple. Critics of adopting this hard line view note that the distinguishing element Röntgen brings to the picture is his willingness to investigate when he saw something that logically should not have appeared before his eyes (the image of his bones through his opaque skin). In Crookes's case, for instance, he did not ask what could be gleaned from the fogged plates. Instead, he returned the tubes to the manufacturer with the claim that they were defective.

Neither the Fleming nor Röntgen discoveries fit cleanly into a multiples category. Still, both are often, correctly, classified as products of their time. These examples demonstrate that some discoveries are more complete than others. In addition, both examples raise the question of whether unexpected discoveries should be considered as equal to similar discoveries that were made earlier when the earlier 'discoverers' decided not to pursue what they noticed. Finally, these examples raise the question of whether there is a contradiction regarding discovery embedded in the multiples definition. In other words, the multiples definition does not convincingly account for anomalies that were 'seen' and ignored a number of times before the individual credited with the discovery recognized that he was seeing an event worthy of investigation.

These brief examples illuminate why some state that characterizing unexpected discoveries as multiples omits the importance of identifying a problem to solve, attention, background, training, and interest. Attention, background, training, and interest also speak more to the importance of the individual in discovery than social construction or a particular methodology. Examples that focus on the individual in turn raise the question of how each individual is related to the broader community environment. This is explored in the next section by turning to examples that combine science and the visual arts.

## III. SCIENCE AND THE VISUAL ARTS

The literature regarding visual art has always characterized multiple discovery somewhat differently from what is found in science and social science publications. For this reason, many social scientists argue that multiple discoveries are not applicable to the visual arts. Yet, the diversity of art and art as a practice show that the art within any particular culture is compatible with ideas about multiple discovery in a general (contextual) sense. This is because art has been a part of all cultures and has also developed along with cultural traditions. Moreover, throughout most of history artistic styles have changed gradually, reflecting that practitioners made subtle refinements as the cultural wisdom passed from generation to generation. One result of this gradual evolution is that it has often been difficult to look at the art of a culture and idenify the hand of any one particular artist. In part this can be explained by the fact that a good artist was not striving to achieve something new. Rather, the belief was that good art was art made according to time-honored formulae. Toward this end, artists generally used traditional tools and techniques to produce a product that conformed to the community's standards.

Within this matrix, some cultural periods stand out as exceptions to this statement. These periods thus offer benchmarks useful in bracketing the practice of art in relation to multiple discovery. Well known benchmarks include (but are not limited to) classical Greece, Renaissance Florence, Elizabethan London, and the 19th century fin-de-siècle. The styles associated with these periods are distinct and thus capable of demonstrating how particular artists have invented new technologies, re-defined long-standing formulas, and altered time-honored practices.

Two points are critical here. First, in the visual arts, as in science, we can identify both multiple and singleton contributions. Second, because artists produce a different kind of product than scientists, and have different intentions when engaged with the practical problems that govern artmaking, it is harder to integrate art into the type of contextual presentation identified with multiple discovery in science. This section cannot comprehensively address the difficulties and will present three case studies (the invention of oil painting, Galileo's illustrations of the moon, and the impact of photography on 19th century painting) to offer an overview that combines science and art. Before proceeding to the specific examples, it should be noted that while art and science are often represented in terms of dichotomies (e. g., imagination and logic, objective and subjective, inner and outer), scholarly work in the history of art has increasingly acknowledged that these kinds of dichotomies distort the many interactive elements that are a part of discovery in art. The use of dichotomies thus tends to obscure that visual artists and scientists alike grapple with concrete materials and subtle relationships. As they do so, their work combines theory with experiment and the individual, probing mind with the products that result.

## A. Individual contributions and multiple discoveries

### 1. The invention of oil painting

Two early sources on the lives of artists, Giorgio Vasari's *Lives of the Artists* (1550*)* and Karel van Mander *The Lives of the Illustrious Netherlandish and German Painters*, from the first edition of the Schilder-boeck, (1603-1604), described oil painting as a sudden technical innovation that was discovered by Jan van Eyck (~1395 – ~1441) after much experimentation. In recent years extensive documentation has established that many painters were experimenting with oil, even as far back as the 8th century. What van Eyck (and other Netherlandish painters) did was see the optical possibility of using systematic glazing to make a painted surface look more realistic. Still, and despite the evidence that clearly documents the invention of oil paintings was a cultural (and thus a multiple) discovery, research has yet to explain why people continue to be drawn to agree with the attribution of priority to van Eyck. His paintings are often introduced in books with the statement that in viewing them one can see why van Eyck had long been credited with the invention. This tendency to attribute the discovery to van Eyck is then explained by looking closely at his work and at descriptions of van Eyck's virtuosity. For example, to demonstrate that van Eyck knew ways to make oil paint behave that no one had displayed before him, the eminent art historian Erwin Panofsky wrote that van Eyck's eye operated as both a microscope and a telescope. As a result, according to Panofsky, the beholder's eye is compelled to oscillate between a position reasonably far from the picture and many positions very close to it.

In sum, it is because the art establishes these complex relationships with the viewer that people are inclined to agree that Van Eyck was not a technician. He had a style of application most of his contemporaries could not duplicate, even when using the same materials and a comparable approach. This evaluation highlights that something particular to van Eyck is evident in his paintings. His 'eye,' his attention to detail and color relationships, his patience in application, and the rich quality of his descriptive product cannot simply be reduced to his knowledge of painting techniques and the evidence that the invention of oil paint was actually a multiple discovery.

### 2. Galileo and the moon

Galileo Galilei's illustrations of the moon expand on the van Eyck example. Galileo also offers an example that explains why many claim that what an individual contributes by virtue of his or her unique background needs to be factored into multiple discovery discussions, for individual contributions often show that discoveries can reflect a community larger than the particular field in which the multiple is generally explored. Briefly, the activity of looking at the moon and other planetary objects through telescopes excited many scientists early in the 17th century. What set Galileo apart from his contemporaries was that he had some training in drawing and watercolor. He also had a relationship and ongoing correspondence with the artist Lodovico Cigoli. Thus, while research has convincingly shown that the telescope was a multiple discovery, a multiples explanation per se deletes that Galileo brought a cognitive advantage to the activity of deciphering what he saw when he looked at the moon through the telescope due to his background. This need not be defined as innate genius. Rather the advantage was environmental. His training in artistic perspective made him aware of how to translate a three-dimension surface onto a flat plane. Because he understood how to create a naturalistic rendering of the rough texture he was able to convincingly convey the nature of the moon's terrain, and to do so in a way that allowed his peers to fully interpret what they saw.

Galileo's now well known astronomical observations/illustrations were published in *Sidereus Nuncius* (*The Starry Messenger,* 1610). In the text Galileo both includes paintings of what he saw when looking at the moon and explanations of how he observed the geography of mountains, valleys, and craters through his telescope. By making reference to how the light and shadows change their disposition as the moon moves from one phase to another, Galileo forthrightly asserts the difference between the terrain he saw and the long-standing Aristotelian belief that the moon must be a smooth surface. The unique body of knowledge he brought to the project and his contacts helped him overturn a longstanding cultural meme and the prevailing Aristotelian idea that the moon was a smooth surface.

Ironically, the information about the moon's texture information was readily available even to the inquiring and thoughtful naked eye, despite the tendency to explain it away. In fact, William Gilbert, best known for his research with magnetism, had earlier produced naked-eye maps of the moon's geography. The outstanding element here is that Gilbert's maps did not draw upon the perspective techniques Galileo knew and used to render a naturalistic picture. In Gilbert's studies it was hard to decipher that the moon had a geography similar to that of the earth. Thomas Harriot offers aanother counterpoint. He is now generally credited with making the first rendering of the moon as seen through a telescope and thus has the somewhat dubious distinction of being one of the first to fail to 'see' the rocky surface until viewing Galileo's images. Having no previous cognitive understanding of how a rough 3-dimensional image would appear on a lens, Harriot, it seems, did not conceptualize he was viewing ridges and shadows — until he had Galileo's work to reference. Harriot, too, was among those more constrained by Aristotle's view that the moon was smooth despite the evidence we see with the naked eye.

The differences among these images and the conclusions drawn from them explain why critics of multiple discovery say the multiples concept is overly generic. By reducing discovery to loosely defined products (like oil paint and the discovery of the telescope), the concept under-emphasizes how attention, experience, and training inform discovery. In light of this, it should be mentioned that historians of science have long been interested in the community of science and multiple discovery complements this area of community by showing scientists comprise a community in which all scientists participate. Galileo's illustrations likewise affirm the scientific valuation of community and add that the more communities connected to a particular scientist, the more potential there is to bring information outside of one's domain into one's creative ventures. Galileo's work also demonstrates that scientific discovery has often been fostered by cross-disciplinary exchange and that cross-disciplinary examples inform the shared problems / parallel product style of inquiry. History, however, also offers examples of multiple discovery that underline a community tends to explore several lines of inquiry simultaneously, even when addressing one product or discovery. This accounts for the tendency to see products in *Zeitgeist* terms. Yet, for example, the painter Jan van Eyck produced three paintings in the 15th century that included naturalistic depictions of the moon's rocky terrain. His paintings, unlike Galileo's, were not included in the philosophical and scientific discourse, where it was unquestioned that the moon was smooth.

### B. *Zeitgeist*

The history of photography speaks directly to the *Zeitgeist* issue, offering a classic case of how artists and scientists often work on problems in tandem. In this case, practitioners in both domains were interested in developing better methods for representing the world we see. This is not surprising given that representation has been an ongoing practical problem for both artists and scientists, and a practical problem easily separated from the philosophical arguments centered on 'appearance' and 'reality.' Many of the pre-photography solutions (the *camera obscura,* the *camera lucida*, studies of optics, and perspective) aided the hand and the eye tremendously. But what was wanted was something that would allow an individual to fix an image and forego the need for long calculations and/or systematic tracing. Eventually determining a combination of light and chemicals capable of copying and fixing images solved this problem. The exciting solution, photography, made it possible to record visual images permanently and offered a level of detail that led some to exclaim that it was like looking at nature with a telescope.

Many helped develop this exciting technology. As early as 1727 a German professor of anatomy Johan Heinrich Schulze had shown it was possible to render images using sunlight and silver salts. In England, as early as 1802, Thomas Wedgewood, the son of the famous potter Josiah Wedgewood, successfully recorded images on paper. In 1819 the chemist John Hershel, the son of William Hershel, the discoverer of the planet Uranus, likewise discovered how to fix images and by 1839 could print them on paper as well. Independently, William Henry Fox Talbot, an English scientist who became interested in the problem because he was unable to draw easily using a *camera lucida*, determined how to create a single negative from which multiple copies of positive prints could be made. The Frenchmen Joseph Nicéphore Niépce and Louis-Jacques Mandé Daguerre conducted other independent investigations early in the 19th century. Their experiments grew out of lithographic techniques and eventually, after Niépce's death, Daguerre fixed a single positive photographic image (a daguerreotype) on a metal plate coated with chemicals and exposed to light.

Assuming these examples represent multiple discoveries, and many think this is an incorrect assumption, does not explain why the mechanical representations of nature changed the cultural environment of art in ways quite unlike their influence on science. This aspect of multiples is of great importance to how one defines creativity and to how one applies the *Zeitgeist* characterization to multiples. Some elements of disparity thus need to be briefly explored. This inquiry will clarify that multiples take form in a context and form a context as well.

In a general sense, the photographic image provided a means for both scientists and artists to quickly record information about nature. Many found the efficiency attractive and astronomers and others quickly adopted the camera as a professional tool in the natural sciences. They immediately saw the technology eliminated the bothersome tasks of drawing and were pleased to no longer have to bear the burden of tracing moving images (although early prints often included after-images). In addition, the images satisfied several cultural demands. These included the desire for relatively inexpensive images for books (or as separate items) and the desire for cheap portraiture. The way in which the camera could record faces was a source of so much delight that some enthusiasts marvelled at how the camera was able to make the fugitive images of the mirror permanent.

The excitement, however, was not all-embracing. Generally, there was some concern that a photograph could be staged to give the impression it was a snapshot and thus be used to deceive people about events. Moreover, especially in the arts, many still preferred something included in the cognitive exercise of rendering by hand and eye. Even those artists (e.g., Manet) who did choose to incorporate the possibilities the camera offered had reservations about the mechanical nature of photographic reproductions. This is not to say that artists were against reproduction per se. Art has always been reproducible in principle, and multiples had always been printed using various technologies (e.g., woodcuts, etchings, etc.). It was the mindless mechanical reproduction of the camera that was disdained. Critics felt the camera was only capable of rendering surfaces. This argument was not a 'multiples' (Talbot's technique) versus 'singleton's' (the daguerreotype) argument in regard to the multiple discovery of the photographic process per se, although the differences between the two processes were a part of the argument. Rather, the concern centered on the mindless nature of the mechanical images and whether mechanical images of surfaces could capture all that art and reality include. In other words, people believed, rightly, that mechanically produced copies did not contain the history, the pulse, and the depth of understanding embodied in an original.

In terms of *Zeitgeist*, the photographic images and the multiple reactions beg two questions. First, why did disciples of art and science have contrary reactions to the multiple discovery of photography. Second, how do we define a product of a time. The key point in evaluating these questions is that scientists were more likely to see photography as a tool. Painters, however, felt compelled to compare the nature of their images with those the camera produced. The overall conclusion of the painters was that the mechanical images were not a replacement for painting or a reason to deny that the so-called objective reality of nature was of painterly interest. It would be more accurate to say that 19th century painters continued to see an objective reality and to believe in the importance of rendering it. But the process of evaluating what images include also changed the nature of painterly problems. In sum, photography was one of many discoveries that re-framed numerous 19th century ideas regarding invention, mechanism, discovery, the mind, appearance, reality, the artist, the scientist, nature, seeing, and knowing. Some other factors include the 19th century political situation and the turn toward Romanticism at the end of the 18th and through the mid-19th centuries.

The details surrounding the entry of photography in the 19th century have been introduced to highlight a recurring question in discussions about creativity and multiple discovery: where do painters like Vincent Van Gogh (1853-1890) and Paul Cézanne (1839-1906) fit? Both 19th century painters are hard to reconcile with multiple discovery in a generic sense, especially when a *Zeitgeist* model is implied. Now deemed as superior artists, their work was considered virtually worthless when they lived. What must be stressed in considering how these men 'fit' into models of creativity and discovery are, first, that the paintings done by van Gogh and Cézanne depicted the 'objective' natural world and were thus deeply rooted in the 19th century tradition. This tradition, as noted, included the development of photography. Second, while both men were marginal in their time, each tried to integrate his work while he lived and failed to receive community acceptance. Finally, it is now said that the authenticity of their paintings and they way the forms conjure up a sense of presence that seems to go beyond the surface turned art in a new direction.

Putting these elements together raises the question of how do we evaluate the contextual incongruence the discoveries of van Gogh and Cézanne present? Many have pointed out they were people of their time. Yet, it is hard to align their productive lives and the intrinsic motivation that guided them with the idea that community acknowledgement of one's efforts is an integral part of being a successfully creative individual. It is equally difficult to align their lives with multiple discovery as generally defined. The problem is best summed up by asking why and to what degree are the individual and the culture connected in the discovery process, be it multiple or singleton? While it is true that most highly creative people do achieve success in their fields and are well-respected by their peers, in the visual arts we do find significant exceptions to this. As van Gogh and Cézanne attest, if we assume a discovery is contextually created, that the quality of a creator's work is evaluated by experts and institutions, and that only one who is 'accepted' by the community can be justly deemed creative in a complete sense, we are left with examples where a person, who is not defined as creative during his or her life, has, nonetheless, left behind products that are deemed creative long after the person has died. This time lag is especially problematic if we want to define artistic and scientific creativity using similar terms and in relationship to one another.

## IV. CULTURAL ISSUES AND CONCLUSIONS

Reviewing the historical examples and the literature surrounding scientific breakthrough we find that even in earlier eras there was a tension between the individual genius model of creativity and the idea of a group working together to develop new ideas. For example, the philosopher Francis Bacon's (1561-1626) *Novum Organum* (1620) argues for multiple discovery when he states that discoveries are the products of "joynt labours," of people working together on common problems. The genius model, by contrast, is built on the image of God, the Creator, and glorifies individual accomplishments. Compatible with both theories of genetic determination and theories, the genius model suggests creative insight comes from out of nowhere, as if one is touched by something akin to the divine.

The long-standing debate about multiple discovery, as this article has shown, has raised many questions about creativity that remain unresolved. The issues and debates include: (1) the fact that the contribution of one individual may be significantly more complete than that of another in parallel discoveries, (2) the question of whether multiples theories adequately address individual creativity, especially given the differences between artistic and scientific creativity, (3) the length of time that separates what are termed 'multiple' discoveries, (4) the length of time that separates an individual's creative process of discovery and the community's acceptance of the work produced, (5) whether it is useful to define all discoveries as inevitable products of a time, an idea that *Zeitgeist* implies, (6) the individual priority disputes that have resulted from parallel discoveries throughout history, (7) the greater emphasis on team work in scientific research today, and (8) how the growth of team work makes it harder to recognize the contribution of any one individual. The complexity of these unresolved questions tends to give rise to philosophical explanations. Given this, and although philosophical theory has not been the primary concern of this article, some precedents related to multiples need to be mentioned.

Briefly, both Plato and Aristotle grappled with the ‘one’ and the ‘many’ and did so because each saw human development and education as key concerns. Moreover, despite their differences, both Plato and Aristotle were deeply committed to an inquiry premised on logic and reason. Both were also in agreement that scientific knowledge is universal knowledge and that it is the same for all people, for all times, and for all places. These points of agreement were to become the backbone of natural philosophy and science in the West. As such, Platonic and Aristotelian ideas gradually set the stage for some of the ambiguities that have come to define the concept of multiple discovery today, as well as western views of creativity.

Since Plato and Aristotle have come to be defined more in terms of how they disagree, with Aristotle being seen to emphasize studies of the natural world to a greater degree, it is often overlooked that both men did adopt a language/logic prototype for inquiry. The western allegiance to this prototype is no doubt why the concept of multiple discovery per se works better in a scientific (or verbal) context than in the visual arts. This language/logic preference, moreover, has generally been adopted by cognitive science in their search for universals.

Presently this long-standing preference for logic-based explanations is being counterbalanced by contextual case studies, systemic studies, research into the psychology of history, cognitive-historical analysis, and multiple intelligences research. Within this broad range many possibilities co-exist. One that might foster viable information connecting individual and community approaches is the evidence of brain plasticity now being generated in cognitive neuroscience, for it appears that new tools might offer ways to align the focus on universals with individual case studies. Even if bridging studies are pursued, however, social and cultural interpretations will still have to be judged on their own terms.

Plato, himself, is not only a foundational reference for these idea. He also offers a powerful example of the limitations within critical interpretation, albeit indirectly. Plato, who had a creative mind and was in awe of artistic inspiration in the sense that he saw it as divinely inspired, solved the problem of the one and the many with a philosophy premised on the idea that individuals could all discover the one Truth. In order to ensure it is the ‘right’ Truth, Plato banned artists from his ideal Republic, arguing their facility for imitation could too easily turn people toward appearances and thus turn them away from a genuine engagement with moral purpose. As philosophers, sociologists, and others have often noted, societies that mold people in “one” way cannot be reduced to simple philosophical conundrums. Rather, manipulative social foundations pose numerous questions regarding education, individual growth, and governance. How people answer these kinds of questions, in turn, has a tremendous impact on what we discover in general — as well as conclusions pertaining to multiple discovery. The heart of the issue is multidimensional: How does a society differentiate between a discovery that is a ‘correct’ product in the sense that it is in line with a culture’s norms and the discovery of something that is actually new and unique? How does the dynamic challenge of intergenerational education influence creativity? Each generation needs to be educated, and each educational process must align technological advances with ever-emerging cultural issues. Within this, one over-riding problem is fostering excellence in discovery, be it multiple or singleton. How does a culture balance individual potential and honor models that include structure, cooperation, teamwork, pluralism, and the exceptional?

The exceptional is of exceptional importance within this — especially because exceptional people defy neatly packaged conclusions about multiple discovery, as the example of Albert Einstein's *annus mirabilis* (1905), discussed earlier, shows. In sum, multiple discoveries can be defined as products that emerge from scientific exchange. Within this, definitional challenges exist due to the difficulty in precisely balancing the many variables that contribute to individual and communal change.

## Cross References

Attribution and Creativity, Discovery, Edison, Thomas, Einstein, Albert-, Expertise, Galileo, Genius and Greatness, Creativity Through History, Ideas, Newton, Isaac, Science (creativity in), Theories of Creativity, Zeitgeist,

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Currently the Director of the Berkeley-based Diatrope Institute, Amy Ione is an artist and educator whose work has focused on creativity and innovation in art and science. Her art has been commissioned by the City of San Francisco, has been exhibited extensively in the United States and Europe, and is found in many collections. Her invited academic presentations include the Keynote address for the 2000 San Francisco International Arts Festival, an invited presentation at the Medical Society of London, an art and science lecture for a symposium sponsored by the Qatar Foundation, and lectures at institutes and universities throughout the world (The Mitteleuropa Institute, the Kyoto Institute of Technology, University College London, Wesleyan University, etc.). Her writing has appeared in *Leonardo*, *Trends in Cognitive Science, The Handbook of Neurology, The Neurobiology of Painting*, and many other books and journals. Ione's latest book is *Innovation and Visualization: Trajectories, Strategies, and Myths* (2006). She also served as the Special Editor for a special issue on Visual Images and Visualization for the Journal of the History of the Neurosciences (2008). More information about her work is available at www.amyione-online.com.