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HUMAN ORIGINS: ONE MAN'S SEARCH FOR THE CAUSES IN TIME

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"Alan Walker once said to me, 'It does not matter how much you can convince yourself; it only matters how much you can convince your skeptics'— that is science in a nutshell." Rick Potts, interview, 4/2/99.

Of all the animal species on earth, only humans ask from whence they came. Paleoanthropologists strive to answer the what, the why and the how of that remarkable journey. In a recent article, "Why Are We Human?," Rick Potts, director of the Smithsonian's Human Origins Program, summarized the state of current knowledge:

> Due to the rapid pace of discovery, scientists now have fossils from more than 5,000 individuals as far back as 5 million years. That record offers strong evidence that we evolved from apelike species in Africa, and genetic evidence confirms that our closest biological cousins are the African chimpanzees. Scientists from many different fields agree that humans and chimpanzees evolved from a common ancestor that lived between 5 million and 8 million years ago (1999a:1).

Today we know that as many as 12 to 15 different human-like species evolved in the past. Why did some continue and change while most died out? It is this question that has consumed Rick Potts' life, beginning when he was a ninth grader in suburban Philadelphia's Abington High School. The story of Potts' determination to answer this question reveals much about human evolution and paleoanthropology, but it also offers insight into one scientist's single-minded passion and the development of a new theory—"variability selection"—to explain the why and the how of human origins. This article presents three intertwined stories:

- the development of one paleoanthropologist's career;
- the development of the human species through time; and
- the development of a new theory of human evolution: variability selection.

These three stories illuminate the inextricable nature of scientific advances, human knowledge, and the individual scientist. In addition, the story of Rick Potts underscores the interplay between inherent disposition and environmental influence, no small irony for a scientist whose theory of human evolution focuses on the interplay between the environment and the human lineage's evolving predisposition toward adaptability, diversity, and versatility. The necessity to understand time both as personal time during which an individual life unfolds and as geologic time within which the human lineage evolved is another theme running through the three stories.

The Early Years

In a recent interview, Potts traced his earliest interest in origins to playground discussions with his older brother, today a mathematician. Potts' awareness of a passion for human origins became evident during a 9th grade world civilization class: "When I left 9th grade, I knew I would become an anthropologist and that I would spend my life studying human origins in East Africa. I went to sleep at night dreaming of doing just that." That 9th grade year Potts asked his parents, neither of whom had gone to college, to buy him two books: Desmond Morris' *The Naked Ape* and Robert Ardrey's *African Genesis*. He still remembers devouring the sections on animal behavior.

"By the end of 9th grade I was completely hooked; then, in the 11th grade, I took a half year anthropology course." His brother was studying anthropology at college, and they shared books and ideas. A history and a biology teacher supported Potts' ambitions. "My history teacher shared my passion for understanding time, and we talked many times about the differences between individual and geological time." She invited Potts to take the AP exam even though his parents could not afford the cost (she paid for the exam) and he was not even in the AP history class. That experience and the encouragement of his biology teacher made a deep impression on Potts. By the end of 12th grade, in 1971, Potts chose a local university, Temple, to study anthropology and pursue his goal of studying human origins in East Africa.

The Environment

Karl Butzer had published his ground breaking *Environment and Archaeology: An Ecological Approach to Prehistory* that same year. Potts' first anthropology professor at Temple believed the study of the human past could not be separated from the study of ancient ecology and assigned all his students to read Butzer. In his first two years, Potts immersed himself in biological studies, focusing on natural selection and adaptation. He took courses in cognitive sciences and physiology, fascinated by the connection between brain physiology and behavior, realizing there was no way to separate the study of physical from cultural evolution. His senior thesis on stone tools argued that tools carry information not only about human capacity for technology but also about general human behavior. Comparing stone tools

RICK'S PASSION FOR THE STUDY OF HUMAN ORIGINS BEGAN IN NINTH GRADE....

of successive hominid species meant comparing cultural and behavioral differences among species. All this seems familiar today, but in the early 1970s studies of stone tools usually meant statistical studies describing various types of technologies, with no reference to such larger issues of behavior or culture.

Graduate School

Potts went straight into graduate school, choosing Harvard primarily because several of its professors called him for interviews ("I felt as if I was a sport's team recruit; I had not heard much about Harvard given my humble roots, but I was impressed by their interest in me.") Neanderthal specialist Erik Trinkaus, then a young assistant professor, read Potts' application, commenting that "he seemed all over the place." A year later Trinkaus remembered his comment and told him: "Now I understand you want to focus on only one thing, but you want to take everything into account to do it."

Paleoanthropologist Alan Walker, then also teaching at Harvard, became a mentor. Most importantly, he arranged for Potts to do his Ph.D. research on Olduvai Gorge, gaining Mary Leakey's blessing for the work. Thus began the last phase in Potts' journey to become a paleoanthropologist—working in the field. First he was to travel to France to gain experience at several

archaeological excavations, then to East Africa to work both at Olduvai Gorge in Tanzania and at the Kenya National Museum in Nairobi, Kenya, to work on the materials previously excavated by Mary and Louis Leakey at Olduvai Gorge. Rick Potts was 23 years old, it was 1976, and he was about to live out his boyhood dream.

Potts explained that in the 1960s and even the 1970s, the study of human origins was still about finding fossil bones and analyzing stone tools, particularly for the early Plio-Pleistocene period of 1.5 to 2.5 million years ago. Researchers were not yet really concerned about behavior or landscapes. "It was a wonderful time for me to be starting out, with my growing interests in ecology, behavior and natural selection."

The Evolution of Early Humans

The context for understanding Potts' research activities over the next two decades is the story of human evolution, a story he has recounted in several popular accounts of the process that transformed a 5-million-year-old tropical ape into a human species of worldwide influence (1999a). Distinctively human qualities emerged over a period of about 5 million years rather than all at once.

As Potts explains the dramatic story, walking regularly on two legs (bipedalism) was the first big step, forever altering the way our ancestors interacted with their environment. By 4 million years ago, apelike individuals (the australopithecines) had evolved who were bipedal but retained an ability to climb trees. Their brains were about one-third the size of a modern human's, they weighed between 60 to 108 pounds, and their height ranged from 3.5 to 5 feet tall.

Either among the australopithecines or the earliest members of our own genus *Homo*, stone toolmaking began to be common by about 2.5 million years ago. The earliest fossils of *Homo* are at least 2.3 to 2.5 million years old, a time period that also sees an increase in cranial or brain capacity. By 1.9 million years ago, the species *H. erectus* had reached modern human size and body proportions and was fully committed to bipedal walking. *H. erectus* was the first hominid to leave Africa, spreading to Asia by about 1.6 million years ago. *H. erectus'* brain size, however, was not fully human, on average only about two-thirds to three-fourths that of fossil modern humans. The relationship of *H. erectus* to the various species before it is still hotly debated. How later fossil humans with modern brain size are related to ourselves is also controversial, particularly in the case of the Neanderthals. (For more information on these current controversies, see Brooks, 1998a,b.)

Only after the brain had reached modern size do we see the complex behaviors we associate with being human: art, clothing, complex stone technology, symbolic representation, and religious behaviors such as burial. These emerged only within the past 100,000 years. Although there is no complete agreement among scientists to explain the emergence of fully modern humans, it is agreed that our species, modern *H. sapiens*, has been the only human species on Earth for at least the last 25,000 years. It is only within the past 10,000 years that farming and herding, cities, writing, trade and warfare arose.

As should be clear from this brief synopsis, humanity's features emerged over time; there was no single threshold or step when humans originated.

Olduvai Gorge

It was to examine early stone tool development that Potts traveled to East Africa to do the research for his Ph.D. In 1977 he arrived in Nairobi, Kenya to re-analyze the fossil bones and stone tools discovered and described by the Leakeys, as well as to analyze other data from Bed I of Olduvai Gorge. It was Mary and Louis Leakey's work at Olduvai Gorge (1936-1985) that had helped shape scientific and popular ideas about the earliest origins of human behavior. It was they who tried to identify the maker of the early "Oldowan stone tools" and to clarify early hominid technology and activity at Olduvai Gorge, then considered the world's oldest archaeological site. Today, the Oldowan industry has been dated to at least 2.5 million years at older East African sites and lasts with little change for about 1 million years. To some specialists such as Glynn Isaac, the pivotal question in the archaeology of early humans was to explain "how high density clusters of stone artifacts and animals bones were found together"(1994:8).

New taphonomic studies had begun to document the processes by which fossil bones and associated stone artifacts were deposited, damaged, and buried over time. Processes such as water transport or feeding by

carnivores could alter what archaeologists found millions of years later and, therefore, could influence archaeological inferences about hominid activity. Potts and his colleague Pat Shipman conducted a groundbreaking study on bones from Olduvai Gorge using the scanning electron microscope, comparing marks on fossil bones with marks produced by known causes (such as carnivore activity or damage from excavation) on modern bones. In the journal *Nature* Potts published his first major scientific paper, describing how stone tool marks could be distinguished from damage to bones made by carnivores and other taphonomic processes. With a clearer understanding of human and carnivore tooth marks, Potts now had a way of seeing how early human toolmakers and carnivores had overlapped or interacted (1981). He concentrated on the hominids' ability to make and transport tools over long distances, freeing them from the apes' "eat as you go" survival strategy. The hominids' transporting tools and food to a single place was a critical transition to creating single places of rest, later known as "home base campsites."

Potts' first book, *Early Hominid Activities at Olduvai* (1988), summarizes his detailed re-analysis of Olduvai hominid behavior that explained site formation. Four levels of analysis are detailed: How did the site form? What did humans do there? How did the different sites at Olduvai reflect different activity patterns in space? How did the hominids' activities change through time?

In the late 1970s, while Potts was preparing his Ph.D. dissertation, Glynn Isaac published his influential articles describing home base sites, places where hominids apparently gathered together over one million years ago to share food and tools (1978). Other anthropologists had been studying home base behavior among modern hunters and gatherers, and Isaac proposed an analogy between these societies and the early hominid ancestors. In his dissertation, Potts used studies of taphonomy, water transport, and landscape analysis to challenge Isaac's view. Contrary to Isaac, Potts concluded that the Olduvai sites did not represent home bases; instead, the earliest hominid sites at Olduvai came before home base development. Based on his re-evaluation of the Oldowan material, Potts asserted that hominids collected stone materials and parts of animal carcasses, obtained through scavenging and hunting, and left them at specified locations, so-called "stone caches," for future processing. In fact, carnivores like leopards and hyenas, attracted to the carcass remains, would have prevented the use of these sites by hominids as the places of primary social activity implied by the home base theory. Potts called his hypothesis "resource transport" (1984, 1991). It was a major theoretical breakthrough, made before he had his Ph.D. in hand, and it was well received by older colleagues in the field, including Isaac.

In 1983 Potts, then an assistant professor of anthropology at Yale University, returned to Africa, this time to direct paleontological/archaeological excavations

at Lainymok, Kenya. Mary Leakey traveled down to visit Potts' excavation, and, impressed with his work, she suggested he turn his attention to the much larger area of Olorgesailie (Oh-lorg-eh-SIGH-lee). The following year Potts gained permission from Richard Leakey, Director of the National Museums in Kenya, to work long-term at Olorgesailie. By 1985 the Smithsonian's National Museum of Natural History had hired Potts to start a new Human Origins Program at the Institution. Within a year, he wrote the first of many grant proposals to fund large-scale excavations at Olorgesailie. Potts' career was launched.

Olorgesailie

For an aspiring paleoanthropologist, Olduvai Gorge was a dream come true, but it was Olorgesailie that changed Potts' life. In the beginning he was after bones and tools and the opportunity to test some ideas regarding home bases by enlarging the context of hominid behavior. To do this work, Potts began to develop a landscape-scale approach to the excavation and study of hominid tools, animals bones and the overall environment. At a single level, 990,000 years old, Potts' team excavated many sites including a huge elephant butchery site. For several summers Potts' team worked to reconstruct the life ways and environmental context of *H. erectus*, 1 million to 600,000 years ago. Potts differentiated his approach from fossil collecting; he was searching to understand the ecological niche of early humans by focusing on excavating an entire landscape, not just surface collecting across the land or putting another fossil onto the family tree.

Soon, however, Potts had begun to ask new questions regarding space and time. What was the ecology of the region through time? What habitats did the various hominids living there have to cope with over a million years in time? With the new dates available at Olorgesailie, Potts realized he could document an entire sequence from 1.2 million up to 49,000 years ago. It was, he said, "an archive of environments, a textbook of hominid behavior...the Rift Valley writ large through time." To analyze and assess this remarkable "archive through time," Potts again assembled an international team to excavate and synthesize the complex data. Potts has always stressed a team approach, working with "geologists, archaeologists, paleontologists, environmental scientists, and a great group of well-trained Kenyan excavators."

Environmental Oscillation

By the early 1990s environmental issues had come to the forefront of public attention and scientific concern, resulting in new research and multiple techniques to measure environments. Potts adapted these techniques to understanding past climates, environments, soils, and vegetation—applying many of these new techniques to his amazing "slice through time." (1998a: 96-104). What he found was startling. The dating and stratigraphic analysis at Olorgesailie uncovered a widening variability through time. Furthermore, Olorgesailie was the tantalizing lead-in to an examination of the larger global picture of environmental change. Looking at the incontrovertible evidence from soils, vegetation, and lake sediments worldwide, Potts could no longer avoid the key word: oscillation.

By 1992 Potts had become committed to understanding the impact of environmental change on early hominids. Much of that year Potts spent walking up and down the hillsides of the site. "I could walk up a hillside and see the bands of the blinding white sediments of the lake replaced by grey and brown soils followed by the thin salt layer indicating the lake had dried up. But then a little further forward in time, the lake would be back. You walk up and down and the oscillation of the environment becomes unmistakable, and you realize that that was the challenge to the hominids, the oscillation of the environment." But how did that challenge operate?

East African Mammal Study

In 1992 Potts thought constantly about the extreme environmental variability he saw as the crucible through which the human lineage had passed. He kept asking himself where had all our human versatility and diversity come from; and if and why humans had evolved differently from other animals, whose evolution he had studied for years. "If natural selection is going to hone an organism's characteristics to the specific environment in which it lives, then how do you transform a small population of apelike hominids into a species of world-wide influence, diverse and extremely flexible in their

behavior. That is the critical ecological question of human evolution."

Understanding the adaptive challenges for other East African mammals might be a key. As Potts explains, with humans we have no comparison, we have the unique situation of human evolution, and our only comparison is with earlier hominids who did not survive. So Potts turned to a study of large mammals in Africa, re-analyzing the fossil animals from Lainymok, a large and diverse sample ideal for such a study. Together Olorgesailie and Lainymok span the time period during which modern human brain size developed—a critical time period for human evolution. Potts and a colleague Alan Deino published their analysis documenting the extinction of an entire group of mammals during this period, around 400,000 years ago (1995). They hypothesized that large numbers of mammals became extinct as a response to rapid climatic fluctuations and extreme dietary specialization. As the mammals eating coarse, low-lying vegetation became extinct, smaller, more versatile, and more generalized eaters emerged; these are the large mammal species still with us today. Potts wondered if the human lineage had gone through a similar pattern of extinction and adaptation as a response to extreme environmental change.

A New Book

In 1990 Potts had signed a contract with William Morrow publishers to write a book dealing with Olorgesailie and environmental change. He wrote half the book and then in 1992 realized his entire thinking was shifting. "I had a series of brainstorms at night, wondering if and how environmental oscillation had been the major influence on the developing human lineage. I realized I had to start the book over again. I called my editors, told them I was throwing out everything I had written, but I promised to start over. I knew I was onto something big, and that it would take time to work out the details. All the training I had in college and graduate school, all the early conversations I had with my brother, all my reading of Charles Darwin flooded back. I knew I had to deal with the question of environmental variability and its impact as a major selective factor explaining human evolution."

Potts realized immediately he would have to challenge one of the major theories and assumptions of human evolution: the transition in Africa from widespread forests to widespread savanna grasslands as the major explanatory factor for the emergence of bipedal, tool using human beings. In his new book, *Humanity's Descent* (1996a), he proposed instead a new theory of environmental variability as the key selective factor explaining the emergence of the human species.

The Savannah Hypothesis

According to conventional wisdom, our earliest ancestors were forced to adapt to a new, drier savannah environment that replaced a once heavily forested landscape. Bipedal walking developed as a favored adaptation to the ground, with hominids using their newly freed hands to make and use tools, especially for hunting. This led to the eating of meat and increased sources of protein that fueled a larger brain. Eventually food sharing, home base living, social interaction, and division of labor by sex emerged. The savannah hypothesis, which Potts was originally taught, had made a lot of sense, but it didn't fit the environmental fluctuations that he had documented. Over the short run some hominids may have adapted to specific environments including the savannah, but over the millennia of time, the human lineage had to accommodate to and cope with huge oscillations or swings in the environment that were manifested all over the world (1998a:109-112).

Variability Selection

It was this variability that Potts identified as the key to the three distinctive breakthroughs of human evolution: bipedal walking (4-1.9 million years ago); stone tool making (2.5 million–1.5 million years ago); and increased brain size (between 700,000 to 150,000 years ago)—each coinciding with increased environmental oscillation. There was a larger amount of savannah in certain areas of the world, but increased fluctuation was just as much a hallmark of global climate and much more influential on the course of human evolution. Potts called his new theory "variability selection," a process that links adaptive change to large degrees of environmental variability. The theory refers to variability as a selection agency, not to the variability or versatility that developed in the human population.

As Potts explains, variability selection "is, in essence, a hypothesis about how hominid evolution has been a response to environments and environmental change."

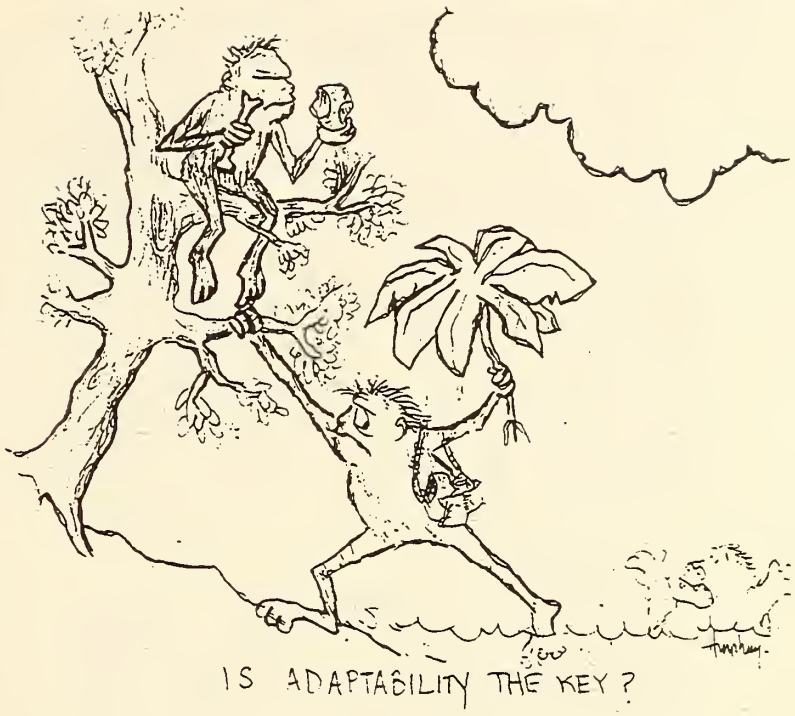
After years of reconstructing environmental variability, as well as the evolution and extinction of mammal species, Potts realized that survival of a versatile species capable of adjusting to novel surroundings was the story of human evolution. As environmental conditions drastically fluctuated, the evolutionary winners were populations that evolved a capacity to respond in new ways to diverse habitats. This process—variability selection—favors genes that improve an organism's adaptability, and the theory explains why our particular pattern of human evolution occurred. As Potts says, " it is not the whole explanation, but I believe it is a critical piece."

Variability selection is also a theory that Potts knows modifies one of the tenets of Darwinian evolution: long-term directional consistency in selection over time, consistency implied, for example, in the savannah hypothesis. In a 1996 article in *Science*, Potts explains the significance of his theory to understanding human evolution: "Hardly just noise, long-term fluctuation was a signal of potentially major evolutionary consequence. I have proposed the term *variability selection* to describe the effects of repeated, dramatic shifting in Darwinian selection over time. This inconsistency over many generations may have had an important impact on hominid evolution" (1996b:922).

Natural Selection

As Potts explains in a recent article: "Natural Selection is the process by which adaptive structures are evolved and maintained. As a result of this century's union of population biology, genetics, and paleontology (the neo-Darwinian synthesis), natural selection is regarded as the main cause of change in organisms in relation to their surroundings"(1998b:81). Traditionally, this meant consistency of adaptation over time. "Selective consistency, or long-term uniform selection pressure, is largely assumed to be the way by which adaptive complexity evolves" (1998b:81). But the adaptive conditions of hominid evolution over time, according to Potts' research, were highly inconsistent on a local to global scale.

Potts' theory posits that inconsistency of environmental conditions had critical implications for hominid evolution. There are several ways organisms can respond to habitat fluctuation (1998b:84-85). The first is simply to follow the preferred environment, an



adaptive pattern that works for a while, but can lead to extinction when large environmental fluctuations occur. The second is to broaden the range of conditions under which an organism can live. This can be achieved by both genetic polymorphism (several different genetic potentials existing within the same population) or by phenotypic plasticity, when organisms can respond differently at any given time with the same genotypic inheritance.

A third avenue of flexibility is "variability selection," or the evolution of adaptive mechanisms within a population which "assist an organism's sophisticated intake of and responsiveness to environmental data" (1998b:85). Examples of such adaptive mechanisms might be new locomotor systems (such as bipedalism) and an enlarged brain to process and generate complex cognitive responses. In light of Potts' theory, the evolution of the brain takes on new meaning, as it is our brain that enables us to adapt to changing conditions, novel problems, and multiple solutions. Climatic oscillation becomes more intense after 700,000 years ago and it is from this time to about 150,000 years ago that the human brain reaches modern size. Potts has stated that his theory requires that we may have to "significantly revise the way natural selection is construed to have operated—not merely as *selection pressure* or as *adaptation to* a model environment, but as

a response to habitat and resource variability from place to place and over time" (1994:23).

Potts points out that in each epoch of human evolution, there were species that evolved as specialists, that adapted to a specific environment and lived alongside more versatile forms that survived after the more specialized forms became extinct. Two examples he cites are the robust australopithecines and the cold-weather adapted Neanderthals, both highly specialized hominids that became extinct. The eventual survival of a single versatile lineage, extraordinarily diverse in its behavior and spread worldwide, may well have evolved as the result of adaptation to our planet's variable environment.

Nature and Humankind

The relationship of nature and humankind is one of the recurring and most thought provoking themes of Potts' popular and extremely well-written volume, *Humanity's Descent* (1996a). "It is important to get the relationship between Nature and humankind right, both in its long-term development and in its present possibility"(44). Potts explains that humans' penchant for setting themselves apart from Nature stems from an illusory divide into natural and human domains...a divide that has "never existed over the long course of human presence on Earth" (267). The implications of this key insight have profound public policy ramifications, for, as Potts says, "the world now rests...on the legacy left by a single species" (44). The fact that our essential human qualities emerged as the result of our ecological relationship to Nature contrasts with the ironic observation that our resulting dominion today could disrupt forever the ecological balance on Earth.

Conclusion

Science moves forward by the process of hypothesis testing, development of new theories, unearthing new data, and proposing alternative explanations. In science, the development of a major new hypothesis or theory is always extraordinary in its originality, but it is, nonetheless, also a beginning; colleagues will test such new ideas with their own data and their own understanding. For Potts, Olorgesailie was the inspiration, environmental change the key to the development of a major new theory to explain human evolution. Variability selection is a dramatic insight and a theory that others now must take into account in their attempt to explain the human past. Potts and his fellow paleoanthropologists will develop other insights, and modifications of Potts' theory of variability selection will inevitably develop through time. But the importance of this new and provocative theory will stand as a major contribution to the ongoing study of human origins.

What Potts' journey demonstrates is that one scientist's approach to understanding the world around him can grow from many seeds: a sharp, fertile mind with a penchant of its own for "the big picture"; an enduring life-long passion to find out where humans came from; and a determination to unravel the whole puzzle, not just a single piece. The influence of teachers, mentors, colleagues, and the scientists who came before, all influenced Potts as he developed through time. Just as his theory connects the development of the human lineage to the millennia of challenging environments, so one can see Potts' life developing from the interaction of his unique mind and driving passion with the influences of his family, teachers, colleagues, and experiences—his environment through time.

Postscript

As this *AnthroNotes* article was being written, Potts flew to London to present his theory of variability selection–at the invitation of the Linnean Society. Potts must have been aware that in July 1858 Charles Darwin and Alfred Wallace, at the urging of the geologist Charles Lyell and the botanist Sir Joseph Hooker, presented simultaneously their papers on evolution through natural selection—to the Linnean Society. On May 24, 1859, Thomas Bell, president of the Society, reported, in his presidential address, that "The year which has passed...has not...been marked by any of those striking discoveries which at once revolutionize, so to speak, the department of science on which they bear" (*1860:* viii). For the impact of variability selection, as with the theory of natural selection, only time will tell.

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