Human Ethology Bulletin – Proc. of the XXII. ISHE Conference (2015): 7-21
Theoretical Review

SCIENCE AS ADVENTURE: THE CREATIVE LIFE OF BILL HAMILTON

Ullica Segerstrale
Department of Social Sciences, Illinois Institute of Technology, 3301 S. Dearborn St., Siegel Hall 116, Chicago, IL 60616, USA.
segerstrale@iit.edu

ABSTRACT

Half a century ago the paper by graduate student William Donald "Bill" Hamilton, "The Genetical Evolution of Social Behaviour" (1964), started a paradigm shift in science. That paper showed how basic social behaviors – selfishness, altruism, cooperation, and spite – could be expressed in the language of population genetics, thus opening the door to mathematical model building and testing. He showed especially that altruism can evolve as long as the benefit of an altruistic act falls on a genetically related individual rather than on a random member of a population. Later Hamilton, ever the pioneer, was to open up many other new research fields. But his ideas were often too novel and he had a hard time convincing journal referees.
What they did not know was the range of methods by which he privately arrived at his conclusions: from "external" naturalistic exploration and mathematical modeling to "internal" anthropomorphic understanding of the study object, to a knowledge state that involved a veritable merger between observer and observed. Colorful computer simulation became the natural mediator between his naturalistic, esthetic and mathematical talents.
Brazil played a huge liberating and stimulating role in Hamilton's life and it became his home abroad, away from his serious Oxford professor persona. He was especially intrigued by the evolutionary puzzles of the flooded forest and helped develop ecological research in the area. The Bill Hamilton Itinerant Center for Environmental and Scientific Education at Lake Mamirauá's floating research station was founded in his honor. Bill Hamilton was an unusual scientist who sustained an intense creativity all his life. For him, science was the best adventure there was, and Brazil was the place to be.

Keywords: *W. D. Hamilton, creativity, social behavior, scientific method, scientific personality, empathy, altruism, Amazon, simulation*

INTRODUCTION

William Donald "Bill" Hamilton was the man who solved one of Darwin's big outstanding problems: why would self-sacrificing behavior in animals ever make evolutionary sense? His 1964 two-part paper "The Genetical Evolution of Social Behaviour" in the *Journal of Theoretical Biology* started a paradigm shift in biology which is still going strong. That paper extended the Evolutionary Synthesis from the early 20th century to the realm of social behavior. By showing how it was possible to formulate the evolution of social behavior in the mathematical language of population genetics, he provided tools for scientists to construct testable hypotheses. In this way he opened up the fields later called sociobiology and behavioral ecology, or for our own species, human sociobiology, Darwinian anthropology, and evolutionary psychology.

Hamilton himself was an ethologist, who later went on to become the first president of the Human Behavior and Evolution Society. While HBES focused on the implication of Hamilton's work for human behavior, Hamilton himself was always aiming for universally valid theories. (Sometimes he had plants in mind).

This article examines some aspects of Hamilton's creativity as a scientist. It is usually not very well known how scientists initially come up with their ideas and convince themselves of their importance - that is part of a "private science" which is typically not published. Hamilton is an exception, in that his autobiographical comments to his collected works, and even some of his published papers, contain hints of this underlying process (Hamilton, 1996, 2001; Ridley 2005). This article is largely based on my book on Bill Hamilton, *Nature's Oracle* (2013), an intellectual biography also informed by letters, notes and interviews.

I am here focusing on those "personal" research methods that Hamilton used to initially assess the viability of his explanation of some interesting phenomenon he encountered. His explanations were always uncompromisingly gene-centered; this was partly a conviction and partly a deliberate limitation. He approached his object of study from the "outside" through close naturalistic observation, always taking the ecological context into account, but, more interestingly, he also reached it from the "inside" by using empathy and unabashed anthropomorphism. He felt a super-natural identification with plants and animals, but his imagination went even further as he sometimes assumed "the gene's point of view" as a pedagogical tool to allow readers to follow his reasoning in early papers (this idea was later developed by Richard Dawkins in *The Selfish Gene*, 1976). He also built physical or computer models to explore a hypothesized evolutionary dynamics.

Hamilton used the same pioneering and risk-taking approach in the field and in his science, always eager to experiment and open up new vistas. But he was also good at eliminating less promising ideas in time. In his private explorations, he acted as a Popperian scientist, following the Darwinian principle of abundant variation and selective retention. This article (and *Nature's Oracle* as well) is my attempt as a sociologist and social psychologist to explore the mind of Bill Hamilton, both from the "outside" (using available information) and the "inside" (using my empathetic imagination).

A PARADIGM SHIFTER

Hamilton's scientific innovation was to change the focus of interest from the individual organism to its genes. This was how he was able to unravel the long-standing puzzle about altruistic behavior. Why would it ever pay for an animal to give its own life (say a bird giving an alarm call or a bee stinging an intruder and dying itself)? Darwin had not been able to come up with an answer. But Hamilton showed convincingly, that from a "gene's eye's view" it may actually pay for an individual organism to behave altruistically if it thereby can help its relatives survive, because these relatives typically carry copies of its genes (with probabilities that have to do with their degree of relatedness). (This reasoning would typically apply to relatives, but it did not have to – Hamilton left open other possibilities, such as some kind of phenotypic similarity, what Hamilton called a "superkinship trait") (Hamilton, 1964).

Hamilton's important theoretical contribution – when he was still a graduate student – was the concept of "inclusive fitness". In addition to individual fitness, this concept takes into account also the individual's effect on the fitness of others and the effect of others on its own fitness. Inclusive fitness is rather tricky to calculate. A popular shortcut, therefore, is "Hamilton's Rule" which specifies under what conditions an individual would theoretically be expected to behave altruistically towards others. The rule simply says that altruism can evolve if the cost to the donor is less than the benefit to the recipient, times the "coefficient of relatedness" between donor and recipient. (That is the probability of two individuals actually carrying the same genes; this is, for example, 50% or 1/2 for parent and offspring, and also 1/2 for two siblings, but 1/8 for first cousins). The term 'kin selection' became a popular shorthand for this principle of the benefits of altruism falling on a genetically related individual.

But for Hamilton, though, solving the puzzle of altruism was only the beginning. He was actually a pioneer type of scientist, who kept going into ever new fields of inquiry. This is what he did best – acting as a trail blazer with his machete, opening up paths in the jungle for others to follow. Among his many contributions were theories involving parasite-host co-evolution, sexual reproduction, mate choice, cooperation between non-relatives, sex ratios, senescence, and conflicts within the genome. Others later took each of these fields further, providing convincing empirical evidence and founding flourishing academic "research industries". For his achievements Hamilton ended up receiving a great number of international prizes and honors, including the Crafoord prize (the nearest equivalent to a Nobel Prize for biology), the Kyoto prize, and the Darwin Medal.

But this happened late in his life. Hamilton's life as a scientist was not easy. He was always struggling with editors and referees who seemed not to be able – or willing - to follow his thinking. Hamilton's ideas were ideas whose time had definitely *not* come! He was often driven to desperation. What he wanted was for his ideas to be discussed and evaluated by his fellow scientists, but that meant that they would need to be published. His difficulty to get his important ideas in press in a timely fashion made him sometimes wonder if he was a crank.

Publications were of course also important for his scientific career. It was the lack of recognition in his homeland, the UK, that initially drove him to the US and to a Museum Professorship at the University of Michigan. Later, the offer of a Research Professorship position at Oxford lured him back.

THE TWO SIDES OF BILL HAMILTON

Many remember Bill Hamilton as a mild-mannered and absent-minded professor. There are famous stories about his lecturing style. Hamilton was fond of scribbling blackboards full with equations while talking towards the board. There are stories of a veritable stampede to the door as soon as the lights went out before his slide show. There are also reports of him stopping in the middle of his own presentation for up to two long minutes, trying to figure out a sudden puzzle (e.g., Anon., 2000, Brown, 2005, p. 355).

But those people who only attended his lectures did not know about the other Hamilton, the supreme naturalist and daring expedition man! That is the "Bill" known to those who followed him on his various research trips. This was a fun-loving and risk-taking fellow, who loved to rough it, and who kept looking for adventure - and if he didn't have it naturally, created it. So he slept with giant spiders in a cave in Borneo and went tiger hunting in India, not to speak of his fearless behavior around the many wasps' nests he collected in Brazil. In the early 1990s at a conference in Tvärminne, Finland, despite serious warnings by the conference organizers about the winter being unusually mild, he skated on dangerously thin sea ice as his colleagues were holding their breath. Hamilton had brought his skates and was set on skating, and that was that! (e.g., Queller, 2001).

Hamilton actually kept cycling between these two main modes throughout his life, the theory and the expedition one. The first one involved intense and frustrating intellectual work. The best example is his four year "absolute obsession" with inclusive fitness (his own description) and later his intense engagement with his parasite paradigm. Hamilton was the type of person who tended to go deeper and deeper into a particular problem, totally absorbed, and often driving himself into a state of frustration and exhaustion. He knew that he would soon have to snap out of this mode and get away. A new environment would be bound to stimulate him and give him new ideas. So here he entered into the expedition mode - but this would also bring the beginning of the next cycle of theoretical work. The insights gathered during his travel would necessarily lead to a new phase of intense theorizing, which again would exhaust him, which would again require distraction by travel, which.... and so on. Throughout Hamilton's life we see examples of this alternation or cycling between the two modes.

And here is where Brazil comes into the story. Hamilton's first encounter with Brazil was in 1963, just after he had got back the referee's report for what would become his famous 1964 paper. He had been told he needed to provide convincing empirical evidence. The journal referee (and his Ph.D. advisers, as well) wanted to know that his theories actually worked in practice! But Warwick Esteban Kerr in Rio Claro had very kindly agreed to be Hamilton's mentor for a year and to use his university as a home base for travels.

Hamilton loved everything about Brazil: the landscape, the language, the people, the food, the fruits, the interesting-tasting drinks (especially those made of the fruit guarana). It must have felt like positive shock therapy, an escape from his somber theoretical self, to be in a sunny place, surrounded by fun-loving and friendly individuals. Serious scientists, yes, but with an appreciation for life, laughter and occasional strong "cafezinhos". Hamilton also discovered the Amazon on this trip and was overwhelmed (Fig. 1). He enjoyed chatting with the Amazonian natives, learning from them an abundance of information about the region's nature. It felt empowering to be able to communicate in a different language. Hamilton is even said to have tried to explain his theory of inclusive fitness to his new acquaintances; they seemed to get it (Kerr, personal communication).

Figure 1. Hamilton in boat on Amazon. Credit: Marcio Ayres.

EXPERIENCING HAMILTON – A FIELD REPORT FROM HIS LAST BRAZILIAN STUDENT

An interesting testimony comes from Servio Ribeiro, Hamilton's last Brazilian student, who first accompanied him on expeditions in the Amazon area and later saw him as a professor at Oxford. Servio describes how their boat sprang a leak and almost sank in a large channel of the Japura river. They had barely time to drive the boat onto the riverbank, where they tried to bail out water and plug the leak for many long hours. Finally, explains Servio, Hamilton decided to try to block the hole in the bottom of the boat with a bed sheet. He jumped into the dark water and remained such a long time under water that everybody got worried. Finally Hamilton popped up, calmly noting that the ferocity of the piranhas was much overrated (Ribeiro, 2000).

Traveling with Bill Hamilton naturally produced a lot of amazing experiences, because, as Servio describes it, "any form of life would be captured by his eyes, touch, or taste. In the position of a student I was invited to taste all kinds of fruits, but also strange things like the flowers of *Spilanthes acmella* (Heliantheae), which turned my tongue senseless due to its high concentration of alkaloids". Servio also notes how his tutor "tirelessly fed and stimulated my own attention toward nice isolated natural events", such as *Azteca* nests and their structure. Bill also explained how seeing the rare black-faced uacari monkey in a malaria-free area was evidence in support of his and Marcio Ayres' hypothesis that the common red-faced uacari had evolved to advertise resistance to malaria. (This referred to the Hamilton-Zuk hypothesis of female mate choice being based on perception of "healthy genes"). (Ribeiro, 2000)

Another typical "Bill" experience was Hamilton's sudden idea for a Ph.D. project for Servio as he noticed a particular fast-growing species of the *Tabebuia* tree that he remembered having earlier seen in Bangalore, India. Maybe high growth rate was connected to resistance to disease and herbivores? This was worth exploring! (Ribeiro, 2000).

So far, Servio had only met Hamilton in his expedition mode. He had come to believe that this *was* Hamilton. The big surprise came a few years later as he was visiting Hamilton in Oxford, now as a Ph. D. student there. "I found myself in contact with a different Bill. This time speaking in English I was re-introduced to a spirited, though shy, man." This time Servio had encountered Hamilton in his typical theoretical mode, totally absorbed in thought (Ribeiro, 2000).

But even at Oxford Hamilton could sometimes lighten up. It seems that when Brazilians visited, they completely changed Hamilton's style. By their sheer presence these students and faculty transported him back to Brazil and the Amazon.

Soon Hamilton went back to the Amazon anyway, more specifically to the Mamirauá floating research station with its special expedition boat. (To this was later added the "Centro Itinerante de Educação Ambiente e Cientifica Bill Hamilton", a center for ecological education). Marcio Ayres, a scientist from Instituto de Pesquisas da Amazonia (INPA) had been convinced that Lake Mamirauá, located at the floodplain confluence of the rivers Solimões and Japurá, would be ideal for an ecological study of the Amazonian seasonal flooded forest. He had invited Hamilton and his colleague Peter Henderson to see for themselves. They immediately linked the Mamirauá initiative to the great British explorer tradition - after all, Henry Walter Bates, the famous explorer of the Amazon and one of Hamilton's early heros, had stayed in nearby Tefé. Hamilton and Henderson enthusiastically applied for and obtained generous funds for the project from British institutions and governmental agencies (Henderson, 2005).

Hamilton loved the flooded forest and the many speculations regarding adaptation that the flooded forest invited. He believed that the plants and animals which were submerged in water at regular intervals were in fact specially adapted for phenotypical flexibility and life-style adaptability. In a joint paper, Hamilton, Henderson and the Oxford student Will Crampton audaciously suggested that the flooded forest might in fact be the cradle for macromutations of various kinds, such as the origin of land animals (via the lung fish) and the origin of trees from plants. This habitat does not encourage evolution through speciation, but through plasticity, they noted and added: "Genetically assimilable plasticity often precedes radical novelty" (Henderson, Hamilton and Crampton, 1998).

CREATIVE CONNECTIONS

For Hamilton, every new encounter with nature was an adventure and a potential opportunity to challenge prevailing orthodoxy. His thinking was quickly moving between general theory and particular, careful observation. If an organism's behavior didn't seem to be explainable by existing theory, well, the theory would simply need to be changed! Because of all the associations and explanations that any new stimulus spontaneously generated in Hamilton's mind, he ended up with a stunning number of new ideas.

But how did he know what to keep and what to leave out? He actually had a method. He was good at "cross-tabulating" various pieces of information in his head for a preliminary check of the plausibility of a particular new idea he might have. He had a set of handy "focal organisms" that he "consulted" in his mind, as he compared and contrasted different aspects. These could be animals, plants, bacteria, fungi, etc. Any new idea would have to pass this rough preliminary test, since he always aimed for universal validity. After that he would go to libraries to mobilize as much supportive evidence as possible from a variety of sources, many quite obscure. Then he would go on to formalize the idea mathematically, build as universal a model as possible and finally test it by simulation.

When it came to creativity-inspiring experiences, Hamilton cast a relatively broad net. He could not know where the next important piece of information would come from. This is also why he censored rather little the type of person that he talked to. In this respect he was quite similar to Darwin, also a relentless fact collector (see e.g., Browne 2002, p.11). Hamilton was also actively looking for materials that would stimulate his thinking - be these old textbooks, maps, or paintings. Old textbooks were a favorite source of information. He loved exploring second hand bookstores and dusty library shelves.

What might be some background factors for Hamilton's scientific creativity? An important point is that his interests did not confine themselves to science. His mother had installed in him a love for great literature and art, and he himself developed an attraction to poetry and a love of language. This exposure to both arts and science provided him with a good foundation. I imagine how in this way an abundance of unusual connections were created across his developing neural networks, connections that he could later draw on when making associations. In fact, he noted himself that he got his idea for one of his models of "seething cycling" between hosts and parasites from the characters in one of Tolstoy's novels. But there was an additional interest of his that served him well. His father, a civil engineer and inventor, had early on taught him how to use his tools, inspiring his son's interest in building physical models. What is more, he had taught him how to think like an engineer.

Hamilton may in fact have lived in some kind of multi-level mental world, rife with potential associations, metaphors and poetic allusions, and connections between science and art. A mediating factor here was probably his love for language. Therefore, "thinking in chords", the expression that Robert Trivers used for his friend, may in fact have become second nature for Hamilton (Trivers, 2002, p. 53).

EMPATHY AS A RESEARCH TOOL

It was Hamilton's mother who first perceived her son's extreme interest in the natural world and encouraged it in various ways. Hamilton was not a regular naturalist. He had an organic connection with the living world. This could sometimes take extreme forms - he was notorious, for instance, for sticking his hands into every hole in the ground, and he is said to have proudly reported that he had been stung by over 1000 wasp species – including his namesake *Stelopolybia hamiltonii* Owen Richards. He liked to sleep on the ground, lulling himself to sleep with evolutionary fantasies.

Bill had a truly unusual empathy with nature. He compared the intense feeling of connection to nature that he felt already as a young boy, to the sensation of love (Hamilton, 1993). The beauty of flowers and the metallic colors of insects mesmerized him. Later he was to take a special liking to the shining carrion beetle, found in the Amazon region (see especially Hamilton, 2000). Among plants, he was partial to the Sphagnum moss. His deep empathy with nature's creatures: plants, insects, even a parasite in his own body made him feel their evolutionary struggle, which helped him in theory building. He could feel the self-sacrifice of the stinging bee.

Later this empathy translated into a pedagogical and methodological device. Statements such as "If I were a gene, what would I do?" or "If I were an Ebola virus, how would I make myself spread most efficiently?" helped feed Hamilton's scientific imagination. As Dawkins later came to emphasize the "selfish interest" of the gene in perpetuating itself, Hamilton himself remained a believer in individual selectionism rather than gene selectionism - that is, he continued treating individuals as statistical "gene packages", something he had learnt from studying Fisher.

Unabashed anthropomorphism was another one of Hamilton's tools. It was both a metaphysical commitment and a method of research. It was clearly crucial in his view of altruism. In his writings one comes across surprising statements such as "the babassu palm embryo is happy to sacrifice itself" or "why shouldn't plants be altruistic" (Hamilton, 2001, xxix-xxx; Hamilton 1996, p. 21).

For Hamilton, nature was animated, full with signals. "Don't come here, I am poisonous" (or, as *New Scientist* cleverly had it "Leaf me alone!") his trees communicated in his Autumn Colors paper, published with Sam Brown (Hamilton and Brown, 2001). Some thought the paper's approach "wacky", but the argument held up (Brown, 2005).

Hamilton was also good at total improvisation – he could turn almost anything into an exciting research project. A good example of this is his fig wasp research. That project was entirely unplanned. Hamilton had in received a grant from England for a comparative study of insects in Brazilian and British old tree trunks. But the place he was staying this time, Ribeirão Preto, sported only very healthy trees. So he decided instead to study and catalogue the only insects around, the fig wasps in the fig plants. He had heard about them but never seen them before. Opening the figs he was taken aback at the ugly creatures crawling out, wingless males with enormous heads, fantastic mandibles and various nasty-looking paraphernalia. But he came to realize that for these wingless males, their only chance to mate was to fight off other males inside the fig. Hamilton could not suppress his empathy, even in his published paper:

"A male's fighting movements could be summarized thus: touch, freeze, approach slowly, strike and recoil. Their fighting look at the same time vicious and cautious - cowardly would be the word, except that, on reflection, this seems unfair in a situation that can only be likened in human terms to a darkened room full of jostling people among whom, or else lurking in cupboards and recesses which open to all sides, are a dozen or so maniacal homicides armed with knives. One bite is easily lethal." (Hamilton, 1979).

LIFE ON THE SCREEN

But it was the computer that was his best tool and it was through computer simulation of his models that he increasingly wanted to prove his theories. (This did not always sit well with referees, typically expecting traditional mathematical proofs). Hamilton was an early adopter of the powers of the computer and had taught himself a range of different programs. Here is an example of his approach. In regard to his parasite avoidance theory of sexual reproduction (the Parasite Red Queen theory), the basic question was: under what conditions would it ever be possible for sexual reproduction to beat asexual reproduction, considering that asexual reproduction, being less costly, had a natural advantage? Hamilton postulated various factors, such as environmental change, and developed dynamic computer models, looking to see under what conditions sex would ever beat asex (as he formulated it) (Hamilton, Henderson and Moran, 1981). Finally, through exclusion, he identified the threat of parasites (pathogens) as the most plausible explanation. An environment full of parasites would induce a population to develop sexual rather than asexual reproduction. Because with sexual reproduction the population would be able to generate new genotypes that could fool invading parasites as these were learning to attack the current genotypes (Hamilton, 1980).

But what would be the exact specifications for the modeling of this phenomenon? What was the required pace of the cycling? By sheer chance, Hamilton found what he was looking for: a slowly moving cyclical co-evolutionary process between hosts and parasites, visualized for him with the help of a computer. (He had actually just tried to adjust the curve parameters to keep the printer head on rather than off the graph paper). This was a moment that he called an "epiphany". He described himself as in his mind actually entering the cyclical process, imagining himself being one of the model host organisms, assessing from the best strategy for escaping parasites, and even finding itself a suitable mate in the process (Hamilton, 1996, pp. 69-72; this also inspired the Hamilton and Zuk 1982 paper). Hamilton stepped into his own model, checking it from the inside.

Hamilton's more typical approach to his host-parasite cycles was "external" in its observations. He enjoyed very much his colorful simulations and treated the best of them as "computer art" (Fig. 2). Here we see the playful ethologist at work - with a bunch of rather unusual critters. As he told one of his close friends:

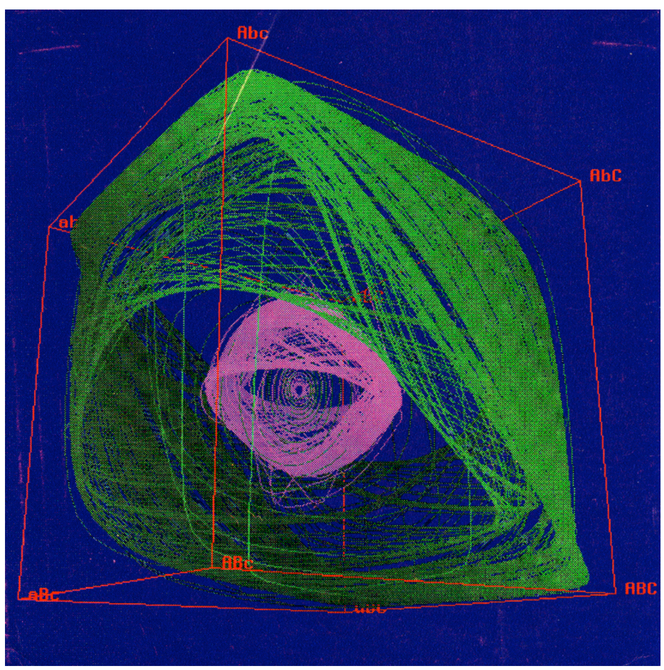

Figure 2. *"Here's an example of the sort of cycle and sort of picture I produce, but not a nice one. I am always hoping to discover the face of God as I generate these cycles, but here I seem to have discovered a rather nasty supercilious eye that watches me. The green trajectory is of the parasite population: it swings wider because having several generations to each generation of hosts. The pink is the host population, nicely herded to near the centre by the sheep-dog-like parasite population racing around, and consequently with no danger of any allele going extinct, which of course I like…"* (Letter to Naomi Pierce, 21 October 1986)

INSIDE INTUITION

Hamilton could watch these dynamic processes on the computer screen for hours. He used to whisper to himself various insights that occurred to him (Sasaki, 2005: Axelrod 2006). The colors of the curves added extra stimulation. He was totally immersed in this work, and as we saw, sometimes imagined himself interacting with it. This appears similar to Einstein riding on a beam of light, which helped him reach the right conclusion.

Hamilton was extremely ambitious with his computer models, but was often told that he was unrealistic. But at the same time he showed amazing capabilities, beyond what his computer specialists themselves could achieve. He could handle extremely complex situations in an intuitive way. One of his computer colleagues once likened him to a musical maestro operating at the very edge of the possible. Here he referred to - of all things - Hamilton's computer program debugging style!

"Many debugging strategies exist, mostly centered around following a single logic thread through the program. Bill's method, however, was more macroscopic. He would look at the entire data output to work out what sort of logical error would produce the results, then back reference to the code to find the sector that violated the logic. Most programmers (including myself) work in the reverse fashion, debugging by examining the code, tracking the values of a single variable or a data structure. *Bill's method was like taking a picture of a freeway system from a helicopter, and by examining the patterns, deduce the position and timing of the stop lights from first principles*." (Sumida, 2005, [italics added]

In other words, Hamilton's strong, almost unrealistic-seeing ambitions were offset by the rare set of talents he had at his disposal, some of which often helped him reach his goal.

This was his visual imagination operating at its best, unraveling secrets and making discoveries. But was he merely watching and thinking? I believe that something else may have been going on here, similar to the experience of many artists, craftsmen and designers, what the Finnish architect and philosopher Juhani Pallasmaa (2009) describes as a "seamless and unconscious collaboration of the eye, hand and mind." I think the following applies also to Hamilton's behavior:

"As the performance is gradually perfected, perception, action of the hand and thought lose their independence and turn into a singular and subliminally coordinated system of reaction and response. Finally, it is the maker's sense of self that seems to be performing the task as if his/her existential sense exuded the work, or performance. The maker's identification with the work is complete. At its best, *the mental and material flow between the maker and the work is so tantalizing that the work seems to be producing itself.* This is actually the essence of the ecstatic experience or the creative outburst; artists repeatedly report that they feel that they are merely recording what is revealed to them and what emerges involuntarily beyond their conscious intellectual control. 'The landscape thinks itself in me, and I am its consciousness,' Paul Cezanne confesses" (Pallasmaa, 2009, italics added).

Exactly this artistic sense of ecstasy could have been how Hamilton felt as he was having that early "epiphany" watching those slow moving cycles. It would seem that interaction with animated, colored computer simulation on the screen would come even closer to the experience described above. In the process of intense watching, Hamilton merged with his own creation.

THE SCIENTIST AS HERO

The pressure to be constantly creative, however, created a dilemma for Hamilton. Not having established a traditional academic empire, he increasingly put himself at the mercy of his individual creativity. At the same time, he felt an urge to do something significant for mankind, his ultimate scientific contribution. This was one of the reasons why he wanted to go to Africa in the late 1990s to collect evidence relating to the controversial OPV (chimp-contaminated polio vaccine) theory of the origin of AIDS which he felt needed to be more closely scrutinized. He had approached the editors of *Science* and *Nature* with a request for serious scientific discussion but been rebuffed. He also believed that possible evidence could be collected, in the form of chimp specimens that might contain the SIV virus. When nobody appeared willing to undertake this task, he decided to do it himself. Unfortunately, the stresses of travel and a bout with malaria brought about a fatal internal bleeding from an undiagnosed duodenal ulcer. Hamilton's death in 2000 came as a great shock to the scientific community (see more details about his last expedition in Segerstrale, 2013, chapter 23).

With his intellectual and physical risk-taking, Bill Hamilton brought back the image of the scientist as hero. Through his example he showed that a scientist could think, say, and do things that on the face of it seemed almost impossible. He was the Indiana Jones of evolutionary science, going off into the jungle with his machete, hacking his way to find hidden treasures and opening up the possibility for truth.

Many thought that Bill Hamilton was surprisingly nonchalant when it came to his own safety. (There had also been some quite dangerous earlier episodes). What if Hamilton had been lost for the scientific world at a much earlier point? What if he had never been born? What would have happened to the theory of inclusive fitness? Or to the parasite theory of sex and sexual selection?

As usual, Hamilton himself had already thought about this and provided his answer. Science is not dependent on the individual scientist. Important scientific truths are going to be discovered sooner or later. Who discovers them and when is partly a matter of accident. Multiple discoveries are typical of science. So, for instance, in regard to inclusive fitness, Hamilton explained, the person who might as well have been credited with the theory of inclusive fitness was his friend Ilan Eshel, who felt and reasoned about many things in a similar way. In regard to the parasite avoidance theory of sex, again, Hamilton's candidate was the naturalist Edward A. Wilson, who was traveling with the Scott expedition aimed for Antarctica and the South Pole when he wrote and then sent from Cape Town a manuscript on the behavior of the red grouse to the *Proceedings of the Zoological Society of London.* Wilson explained the birds' behavior and looks as due to infestation by parasites. He also enclosed some beautiful water colors of the birds, which highlighted typically parasitized areas. Wilson would surely have continued to discuss all this, Hamilton comments, but he tragically died with Robert Scott on the way back from the South Pole. And Charles Darwin himself may have got lost on one of his expeditions. Who would then have substituted Darwin? Hamilton did not say. But he pointed out that every scientist knows that there will be others following in his or her footsteps. Accidents happen to some, but others will follow. Science goes on (Hamilton, 2001, 806-810).

These thoughts of Hamilton's capture the deep meaning of being a scientist. It is being part of a great cross-generational enterprise, where the individual does not necessarily matter. But it is strange to hear this from an individual whose unusual scientific personality *did* matter so much to so many, with its steady stream of path-breaking contributions, interesting ideas, and generously dispensed advice to his fellow scientists.

REFERENCES

Anon., (2000). Professor W. D. Hamilton (obituary). *The London Times*, March 9. (Attributed to John Maynard Smith).

Axelrod, R. (2006). Agent-based modeling as a bridge between disciplines. In K. L. Judd and L. Tesfatsion (Eds.), *Handbook of Computational Economics, Vol, 2: Agent-Based Computational Economic*s, Handbook in Economics Series.

Brown, S. (2005). A view from Mars. In M. Ridley (Ed.), *Narrow Roads of Gene Land. The Collected Papers of W. D. Hamilton Volume 3: Final Words* (pp. 349-356). Oxford and New York: Oxford University Press.

Browne, J. (2002). *Charles Darwin: The Power of Place.* Princeton: Princeton University Press.

Dawkins, R. (1976). *The Selfish Gene*. Oxford: Oxford University Press.

Fisher, R. A. (1930). *The Genetical Theory of Natural Selection*. Oxford: Clarendon Press.

Hamilton, W. D. (1963).The evolution of altruistic behavior. *The American Naturalist, 97*, 354-6.

Hamilton, W. D. (1964).The genetical theory of social behaviour. I and II. *Journal of Theoretical Biology, 7*, 1-16; 17-32.

Hamilton, W. D. (1979). Wingless and fighting males in fig wasps and other insects. In M. S. Blum & N. A. Blum (Eds), *Reproductive Competition, Mate Choice and Sexual Selection in Insects* (pp. 167-220). New York and London: Academic Press. Republished in W. D. Hamilton (1996), *Narrow Roads of Gene Land. The Collected Papers of W. D. Hamilton Volume I: Evolution of Social Behaviour* (pp. 435-482). Oxford and New York: W. H. Freedman.

Hamilton, W. D. (1980). Sex versus non-sex versus parasites, *Oikos, 35*, 282-290. Republished in W. D. Hamilton (1996), *Narrow Roads of Gene Land. The Collected Papers of W. D. Hamilton Volume I: Evolution of Social Behaviour* (pp. 77-91). Oxford and New York: W. H. Freedman.

Hamilton, W. D. (1993). Between Shoreham and Downe: seeking the key to natural beauty. *Inamori Foundation Kyoto Prize Commemorative Lecture*. Republished in M. Ridley (Ed.) (2005), *Narrow Roads of Gene Land. The Collected Papers of W. D. Hamilton Volume 3: Final Words* (pp. 205-219), Oxford and New York: Oxford University Press.

Hamilton, W. D. (1996). *Narrow Roads of Gene Land. The Collected Papers of W. D. Hamilton Volume I: Evolution of Social Behaviour.* Oxford and New York: W. H. Freedman.

Hamilton, W. D. (2000). My intended burial and why. *Ethology, Ecology and Evolution, 12*, 111-122. (Originally published in *The Insectarium, 28*, 238-247, in Japanese. Republished in M. Ridley (Ed.) (2005), *Narrow Roads of Gene Land. The Collected Papers of W. D. Hamilton Volume 3: Final Words* (pp. 73-88), Oxford and New York: Oxford University Press.

Hamilton, W. D. (2001). *Narrow Roads of Gene Land. Volume II: The Evolution of Sex. The Collected Papers of W. D. Hamilton.* Oxford and New York: Oxford University Press.

Hamilton, W. D. and Brown, S. P. (2001). Autumn tree colors as a handicap signal. *Proceedings of the Royal Society of London, Series B, 268*, 1489-1493.

Hamilton, W. D., Henderson, P. A. and Moran, N. A. (1981). Fluctuation of environment and coevolved antagonistic polymorphisms as factors in the maintenance of sex. In R. D. Alexander & D. W. Tinkle (Eds). *Natural Selection and Social Behavior* (pp. 363-381). New York: Chiron.

Hamilton, W. D. & Zuk, M. (1982). Heritable true fitness and bright birds - a role for parasites. *Science, 218*, 384-387. Republished in W. D. Hamilton (1996), *Narrow Roads of Gene Land. The Collected Papers of W. D. Hamilton Volume I: Evolution of Social Behaviour* (pp. 221-230). Oxford and New York: W. H. Freedman.

Henderson, P., Hamilton, W. D. and Crampton, W. (1998). Evolution and diversity in Amazonian floodplain communities. In Newbery, D.M., Prins, H. H. T.and Brown, N. D. (Eds.), *Dynamics of Tropical Communities*, The 37th Symposium of the British Ecological Society, London (pp 385-419). Oxford: Blackwell. Republished in M. Ridley (Ed.) (2005), *Narrow Roads of Gene Land. The Collected Papers of W. D. Hamilton Volume 3: Final Words* (pp. 315-348), Oxford and New York: Oxford University Press.

Henderson, P. (2005). Life, evolution and development in the Amazonian floodplain. In M. Ridley (Ed.), *Narrow Roads of Gene Land. The Collected Papers of W. D. Hamilton Volume 3: Final Words* (pp. 307-314), Oxford and New York: Oxford University Press.

Maynard Smith, J. (1964). Group selection and kin selection. *Nature, 201*, 1145-1147.

Pallasmaa, J. (2009). *The Thinking Hand*, Chichester, UK: John Wiley & Sons, Ltd.

Queller, D. C. (2001). W. D. Hamilton and the evolution of sociality. Hamilton Symposium. *Behavioral Ecology, 12*, no. 3, 261-263.

Ribeiro, S. (2000). William D. Hamilton, 1936-2000, remembered by his last Brazilian student. *Antenna, 24*, 119-121.

Ridley, M. (Ed.) (2005). *Narrow Roads of Gene Land. The Collected Papers of W. D. Hamilton. Volume III: Final Words.* Oxford and New York: Oxford University Press.

Ridley, M. (1993). *The Red Queen*. Harmondsworth: Penguin.

Sasaki, A. (2005). Tomato attractors on the wall of an abandoned church. In M. Ridley (Ed.), *Narrow Roads of Gene Land. The Collected Papers of W. D. Hamilton Volume 3: Final Words* (pp. 369-375), Oxford and New York: Oxford University Press.

Segerstrale, U. (2002). Neo-Darwinism, in M. Pagel (Ed.), *Encyclopedia of Evolution* (pp. 107-110). Oxford: Oxford University Press.

Segerstrale, U. (2013). *Nature's Oracle: The Life and Work of W. D. Hamilton*. Oxford and New York: Oxford University Press. (Paperback version forthcoming 2015).

Sumida, B. (2005). Oku no hosomichi. In M. Ridley (Ed.), *Narrow Roads of Gene Land. The Collected Papers of W. D. Hamilton Volume 3: Final Words* (pp. 349-356). Oxford and New York: Oxford University Press.

Trivers, R. (2002). *Natural Selection and Social Theory*. Oxford and New York: Oxford University Press.