Deep Woods PCR
Responding to the Challenge of BioARTCAMP

Paul Vanouse

> It is not down in any map; true places never are.
>
> — Herman Melville, *Moby Dick*.

The Challenge

BioARTCAMP was an anachronistic, relational and durational micro-theater in the form of an artist residency. Jennifer Willet invited six artists and two scientists to embark on a fully funded expedition to an encampment where we would set up a field station to undertake BioArt projects. It was anachronistic and theatrical in that the year was 2011, not 1792 when Sir Alexander Mackenzie undertook his expedition across the continent unknown to European geographers. However, taking place in the heart of the Canadian Rockies, Willet's proposition challenged us to perform an exploratory gesture, not simply to re-explore this grand and well-preserved wilderness, but to explore an artistic project in the context of this powerful and iconic landscape. Or at least this is how I understood the challenge when I signed on.

During the residency, I produced an artwork—an extended performance—centered on restaging one of the most important biotechnological discoveries of the late twentieth century. However, the idea of exploration

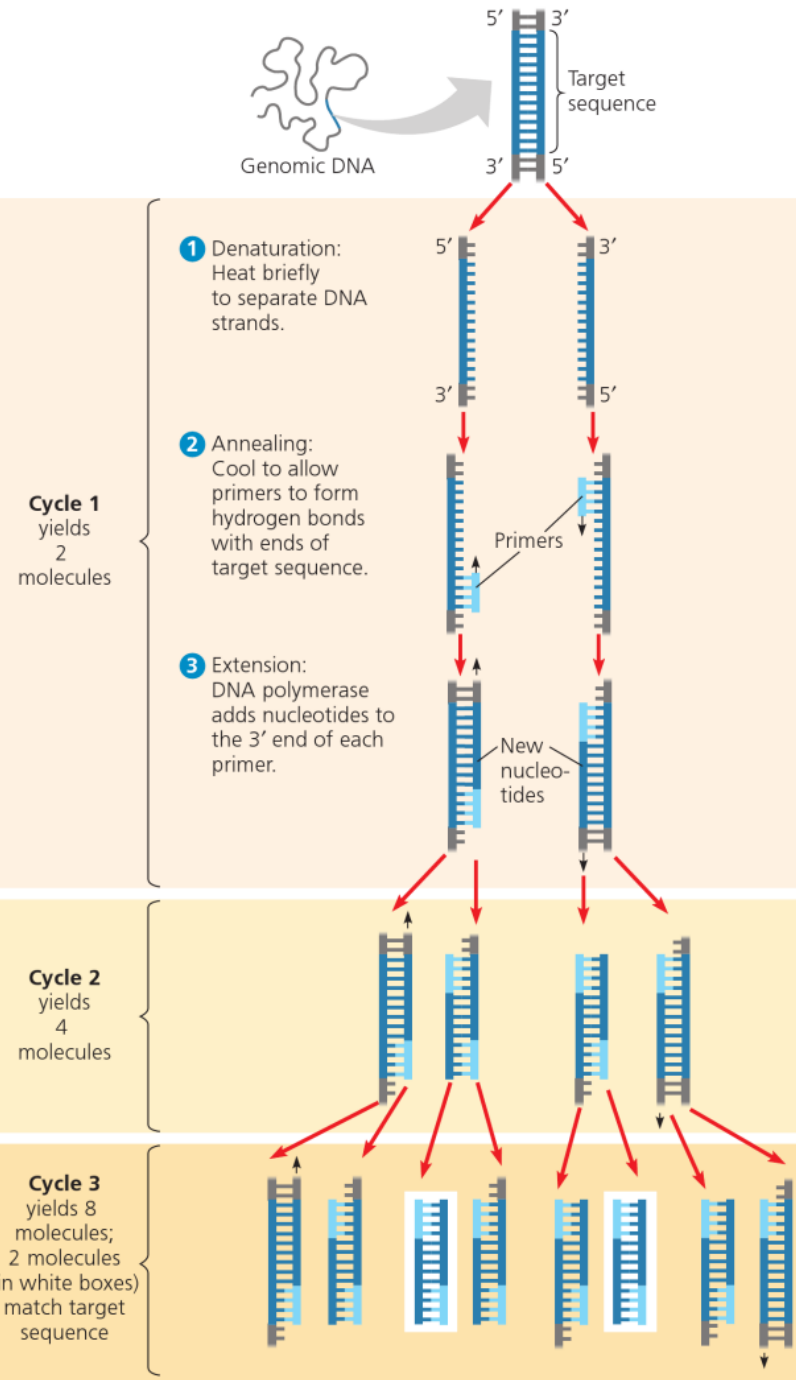
required unpacking before this or any art project could be formulated.

In canonical Romantic exploration narratives, the journey into the unknown is often a vehicle for self-discovery as the external environs force an internal revelation. For instance, Ishmael, the protagonist in Herman Melville's *Moby Dick*, asks that we "consider them both, the sea and the land; and do you not find a strange analogy to something in yourself?"[1] For Ishmael, the journey is a catalyst for self-reflection and the landscape is like a mirror of self. Yet Marlow in Joseph Conrad's *Heart of Darkness* dismantles poetic reflection and exposes the colonial exploit when he asserts that "the conquest of the earth, which mostly means the taking it away from those who have a different complexion or slightly flatter noses than ourselves, is not a pretty thing when you look into it too much."[2] For native peoples, the Banff region was a sacred place where medicines were gathered and healing sought in the hot mineral springs. Soon after the Banff National Park was established in the late 1800s, aboriginal peoples were excluded and traditional hunting and gathering were prohibited.[3]

Biotechnological History: The Polymerase Chain Reaction

I imagined an artistic project that would relate the romantic myth of scientific discovery narratives with those

Paul Vanouse, *Performing Deep Woods PCR at firepit with racoon*, 2011. Performance photograph, Banff National Park, photo credit: Jeanette Groenendaal.


5′
3′
Target sequence
Genomic DNA
3′
5′
1 Denaturation: Heat briefly to separate DNA strands.
5′
3′
3′
5′
2 Annealing: Cool to allow primers to form hydrogen bonds with ends of target sequence.
Primers
3 Extension: DNA polymerase adds nucleotides to the 3′ end of each primer.
New nucleo-tides
Cycle 1 yields 2 molecules
Cycle 2 yields 4 molecules
Cycle 3 yields 8 molecules; 2 molecules (in white boxes) match target sequence

exploration narratives; something with similar affordances for self-discovery; something that also allowed me to reflect or subvert the colonizing tendencies of the sciences. I chose to focus on one process in particular, the Polymerase Chain Reaction (PCR)

The invention of the Polymerase Chain Reaction in 1980 has romantic, mythic dimensions and has been portrayed by its inventor, Kary Mullis, as a narrative of scientific discovery intertwined with self-discovery. The epitome of a scientific pioneer, possessing an irreverent and mischievous curiosity, he grew beyond his area of expertise to invent a revolutionary biotechnology. After completing his Ph.D. in biochemistry in 1973, Mullis began work at the Cetus Corporation to chemically synthesize oglionucleotides (short sequences of DNA), however he became fixated on an aspect of DNA replication that others had never considered. While the oglionucleotides had been used as radioactive labels to stick to corresponding regions of DNA, or as starting points to induce DNA replication, Mullis imagined using two oglionucleotides like bookends, and to allow the cells' own enzymes to exponentially copy the region. Mullis credits self-experimentation with LSD during his graduate work in the Bay area as a fundamental mind opening exercise, alongside his interest in computer algorithms and fractals, without which he may not have conceived of what he coined the Polymerase Chain Reaction.[4]

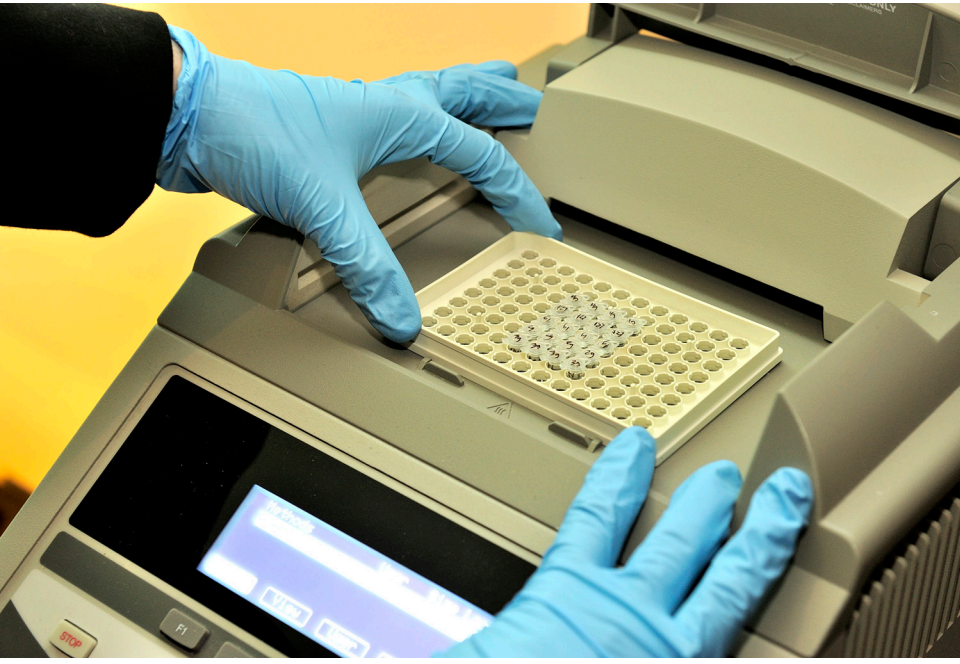
The Polymerase Chain Reaction is an elegant algorithmic process that allowed Mullis to copy a small

Dhurba Giri, *Diagram illustrating the PCR Process*, 2015.[5]

region of DNA billions of times, thereby "amplifying" this small region simply by cycling through the temperatures of a chemical reaction. The process works by first filling a tiny tube with a few microliters of: (A) purified "template" DNA; (B) oglionucleotides of about twenty bases in length; (C) chemically synthesized individual bases, A,C,G and T, called "DNTPs"; and (D) a temperature activated DNA polymerase. When heated to 95°C (Step 1) the DNA is denatured, meaning that the double stranded DNA separates into two strands, at which point copying can begin. When the temperature is reduced to about 65°C (Step 2) the oglionucleotides stick to their complementary sequence on the purified DNA. Then, when heated to 72°C (Step 3) the polymerase copies the region between oglionucleotides by assembling the DNTPs to match the template string. Then, when heated again to 95°C, to begin the cycle a second time, the strands denature and the primers release from the copied strand so the process can be repeated. DNA is replicated exponentially. Within a few years of the invention, the entire process could be performed by a PCR machine, or thermocycler, which effectively black-boxed the technology.

PCR has been utilized as a technology of "self-discovery," but also, less optimistically, as one of authoritarian identification. PCR has replaced earlier DNA typing methods in many legal cases as well as in massive government DNA databasing schemes, such as the American FBI's Combined DNA Index System (CODIS) project. It is the link to identification that particularly interested me in the context of Romantic self-discovery. However, PCR has also been used to clone DNA for DNA sequencing, gene cloning and genetic engineering as well as a myriad of related molecular biology applications.

Kary Mullis, innovator and Nobel Laureate has been described as an impulsive and opinionated oddball who alienated others at Cetus. Varied accounts have Mullis threatening other workers: sometimes carrying a gun and even punching a co-worker at an office party. In the end, he is credited with a big idea that was before its time, one



Paul Vanouse, *Typical DNA Thermocycler from approximately 2010*, 2011. Color photograph, photo credit: Axel Heise. Ernst Schering Foundation, Berlin.

that he doggedly pursued despite his other duties at the corporation. For his discovery, Mullis, along with Michael Smith, was awarded the Nobel Prize in Chemistry in 1993. However, the PCR process—the first great patent of the biotechnological revolution—was prematurely sold by

Paul Vanouse, *Performing Deep Woods PCR*, 2011. Performance photograph, Banff National Park, Canada, photo credit: Jeanette Groenendaal.

Cetus to Hoffmann-La Roche, the corporation which made PCR one of the most profitable biotechnologies of the twentieth century. [6]

Deep Woods PCR

I carried out all phases of the "high-tech" PCR process in the unlikely setting of the deep-woods using stone-age technologies such as the fire pit and three buckets of water instead of a PCR thermocycling machine. My intention was to explore the meanings of the PCR discovery/patent by using a low-tech PCR experiment, a technologically anachronistic reenactment, in the middle of the national forest. The performance conflated the scientific pioneer with a romance of the expedition and probed the idea of "self-discovery" in its widest sense. The full process follows:

Step 1: With the help of Jennifer Willet, who negotiated with the parks department for permission, I collected water from the famed sulfuric hotsprings of the region in order to incubate and extract *Thermus aquaticus* bacteria. This thermophilic organism produces an enzyme, *Taq* polymerase, which can copy DNA at the high temperatures essential to PCR's commercial effectiveness. It was discovered in geysers at Yellowstone National Forest in 1969 and intensely commercialized. In 1989, *Science* magazine named *Taq* as its first "Molecule of the Year." Presently, most commercial *Taq* polymerase is not actually produced inside *Thermus aquaticus* bacteria, but is produced by inserting a recombinant plasmid containing the cloned *Taq* polymerase gene into E.coli cells, incubating the cells and extracting the polymerase.

By attempting to harvest and utilize the original species rather than the patented gene, I sought to assert the microbe's nature rather than its colonized product, while also recalling the history of aboriginal medicines gathered from the hotsprings prior to intensive colonization.

Paul Vanouse, *Jennifer Willet at hotspring in Banff National Park, Canada*, 2011. Color photograph.

Step 2: I extracted my own DNA using an educational kit containing *Instagene Matrix*, from the Bio-Rad company. The extraction protocol involved swishing saline in my mouth for 60 seconds and dispensing into 2 ml capped tubes, adding *Chelex* resin beads (which bind to non-DNA components of cells in the spit sample), heating to actually lyse the cells, then collecting the supernatant liquid containing my DNA.[7] Then I combined—in a 2 ml tube—minute quantities of DNA, Taq, DNA primers designed to target the *Alu 92* gene, DNTPs, and water.

Step 3: I performed the experiment in pioneer fashion, without a PCR machine, but rather by using a campfire. It required that I keep water buckets at precise temperatures: 95°, 65° and 72° Celsius. Then I "thermocycled" the buckets—switching between them 120 times, or 40 cycles of about 90 seconds each. I was simultaneously maintaining water temperatures by adding wood to the fire and shifting bucket placement. This stage was the focus of *Deep Woods PCR* and what I considered the artistic and scientific challenge. It took hours.

Filmmakers Zoot Derks and Jeanette Groenendaal tirelessly documented the event in its entirety. Angus Leech premiered an original composition, *Thermocyclin' 'neath the moon*, which he sang as he strummed his acoustic guitar. Other artists and scientists from the *BioARTCAMP* also joined me at the campfire for the all-night performance, including: Jennifer Willet, Tagny Duff, Marta De Menezes, Adam Zaretsky, Marie Pier Boucher, Kurt Illerbrun, Iain and Louise Chance Baxter&, Bulent Mutus, Grant Yocom, Brit Wray, Jamie Ferguson, Dave Dowhaniuk and Kacie Auffret.

During thermocycling, I attempted to channel Mullis. Rafael Vanouse played the part of a fluorescent green raccoon and repeatedly chanted "amplify the source, not the signal," a phrase that refers to the genius of PCR for DNA analysis. Prior to PCR, scientists seeking to visually analyze DNA fragments needed to radioactively label target sequences and typically they sought better imaging apparatus or stronger radiation to enhance their dim images. Mullis, on the other hand, realized that DNA regions could be amplified exponentially by successively initiating the DNA transcription process and thus greatly enhance any imaging or analytical process. In his autobiography, Mullis describes a benevolent encounter with a fluorescent green raccoon muse that greets him with "good evening, doctor" near his cabin in Northern California. In my rendition, the raccoon is a benevolent trickster who helps Mullis on his journey of discovery.

Step 4: To judge if the PCR worked, I ran the samples in a DNA electrophoresis gel. Miraculously, it succeeded. DNA bands are clearly visible in the second and third lanes of the gel (the fuzzy bands are probably a primer smear, not DNA, but the crisper bands just below are DNA), which means *my DNA was amplified*. Furthermore, these DNA band locations show I am heterozygous for the PV92 *Alu* gene. This genetic site is often used for genotyping, as there is variation across our species. I was not expecting the process to actually work, since PCR reactions are very sensitive and tricky even in laboratory conditions.

Paul Vanouse, *BioARTCAMP participants at the fire pit*, 2011. Color photograph.

Conclusions

Just as context is meaningful in any cultural activity (such as an artistic performance) the context in which PCR was "invented" by Mullis is fundamentally linked to its cultural meaning, economic value, and scientific merit. When Mullis began his exploration, there was a big problem. It had no purpose. The idea of duplicating a region of DNA exponentially was "cool," but of little use in research or industry. However, by the time he obtained publishable results, the technology had been shown to have great utility for genetic engineering (allowing one to duplicate a gene for transplant) and DNA typing (allowing one to compare highly variable regions of DNA). Changing context turns a neat trick into an indispensable laboratory tool.

Mullis's "invention" occured at the brink of the biotech era, while patent laws were being stretched and as private biotech corporations outmaneuvered the university research labs. "Invention" is used in quotes here because every part of this process had already been invented—PCR patents were highly contested by the scientists who had developed the individual components of the PCR process. PCR is only an invention in the changing context of research science, which made Mullis's "idea" unique.

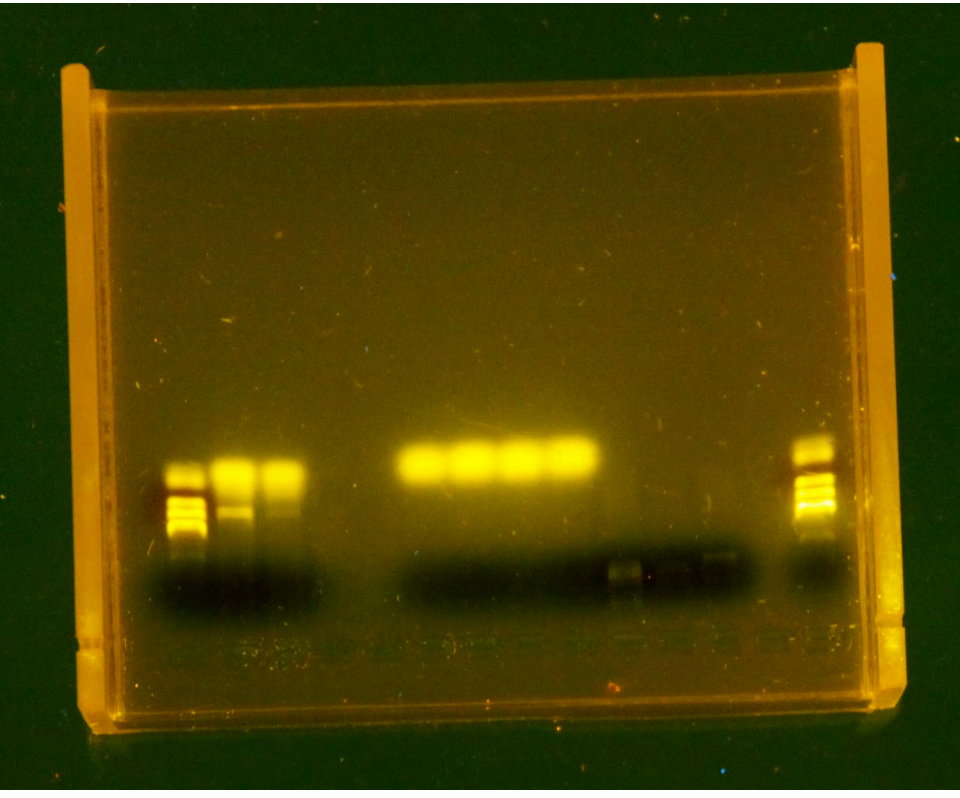
In this sense, perhaps the deep woods context of my own performance does more than highlight the complex play of humans, non-humans and context of technological invention—often called the "actor-network model." Hopefully this amateur using primarily stone-age technology to perform contemporary molecular biology playfully opens doors to other non-specialists seeking informal, non-outcome-driven ways to participate with the techno-sciences.

Postscript

While conceiving *Deep Woods PCR* before *BioARTCAMP*, I had a simplistic conception of Mullis. He was the famed biochemist who could be performed and parodied because he was a public figure with unconventional libertarian opinions and conducts incongruous with societal conceptions of a serious scientist. When I returned from the experience, I reinvestigated and reimagined Mullis's

Paul Vanouse, *Performing Deep Woods PCR*, 2011.
Performance photograph, Banff National Park, Canada,
photo credit: Jeanette Groenendaal.

role in the 1995 O. J. Simpson trial, in which he was in the courtroom as an expert witness for Simpson, but never called to the stand. According to Mullis, the prosecution team had been tailing him outside the courtroom and planned to use



Paul Vanouse, *Final image of DNA gel from Deep Woods PCR, Banff National Park, Canada*, 2011. Color photograph of electrophoresis gel.

his advocacy of LSD to discredit his testimony. As a Nobel Laureate who invented the technology used in many DNA tests, his scientific opinions would otherwise be influential. Mullis thought the idea that the lab doing the DNA analysis was literally run by the prosecution violated standards of objectivity as well as the "first principles" of scientific method.[8]

In 2013, Dr. William Thompson, a member of the "Dream Team"—Simpson's defense team led by Johnny Cochran—relayed to me an anecdote about another idea of Mullis's: to invent a personal privacy spray called "DNA Anonymous" that could be used to mask one's DNA fingerprints. This led me to imagine what might have transpired in the O. J. Simpson trial had Mullis been called to the stand. While the DNA evidence in the trial had been thrown out by Judge Lance Allen Ito because of *chain of custody* missteps by the investigators, it would seem Mullis's testimony might have been more faultfinding of DNA evidence and assumptions as a whole. For instance, perhaps a new precedent for the metrics of certainty would have been reached, or adversarial participation in the laboratory work would have been mandated. Simpson's defense team accomplished the task of a legal defense, to advocate for the accused, whereas perhaps Mullis on the witness stand would have deconstructed DNA forensics for the broader good of the justice system.

Later, in 2014, I visited with Mullis and his wife Nancy at their modest Southern California home. While some biochemists in the 1980s objected to the Nobel accolade for PCR being given to Mullis, he reaped little of the big financial rewards. While the Roche corporation made billions of dollars from PCR, Mullis received only a $10,000 bonus for

his achievement from the Cetus corporation at which he worked. While this, in addition to his half share of a Nobel Prize and speaking fees throughout the nineties, would seem to provide for financial security, the Mullises were not barons of biotech billions. Kary Mullis now seemed more like a (retired) actor in a powerful biotechnological apparatus with replaceable parts. This awareness has underscored my purpose and understanding of *Deep Woods PCR* as a performative exploration of actors and actants, humans and non-humans, protocols and patents, rather than simply as a critique or a parody.

Post postscript

Since I have no doubt strained the conflation of scientific, terrestrial and self-exploration, as well as pushed the analogy between Ishamael and Mullis's explorations and my own performative artwork, I must also prevent the reader from carrying these analogies too far. Specifically, while Ishmael has his Ahab and Mullis his Cetus corporation, my journey with Jennifer Willet was one of equity and collaboration. Willet is not Ahab in this anachronistic imaginary land in which *Deep Woods PCR* was enacted. *BioARTCAMP* however, may well be analogous to a mind opening psychoactive drug, which might be a more suitable comparison.

Notes

1 Herman Melville, *Moby Dick* (New York: Random House, 1967), 293.
2 Joseph Conrad, *Heart of Darkness* (New York: Dover Publications, 1990), 6.
3 Banff & Lake Louise Tourism website: https://www.banfflakelouise.com/banff-national-park/history-heritage. The website notes that "these policies have been reversed over the last 50 years."
4 Kary Mullis, *Dancing Naked in the Mind Field* (New York: Vintage books, 1998).
5 Image source: Dhurba Giri, "Polymerase Chain Reaction (PCR): Principle, Procedure, Components, Types and Application," Laboratoryinfo.com, July 27, 2015. http://laboratoryinfo.com/polymerase-chain-reaction-pcr/
6 Paul Rabinow, *Making PCR: A Story of Biotechnology* (Chicago: University of Chicago Press, 1996).
7 For more information on the extraction process, see the Bio-Rad webstie: http://www.bio-rad.com/en-us/product/instagene-matrix
8 Mullis, *Dancing Naked in the Mind Field.*