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Hot Topic: Videogames in research and therapeutics

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INK CALL FOR ARTICLES

The interdisciplinary Graduate Student Network (iGSN) has launched a non-academic, student-run journal with the intent of bringing together UBC's interdisciplinary community to enhance our sharing of knowledge and spur communication. We occupy a unique niche where students could showcase their work and their fields, and engage in innovative discussion that addresses real world problems. By launching this journal, we are offering a chance to get published and participate in knowledge translation.

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Because INK will contain works from both the soft- and hard-sciences, all articles should steer clear of jargon and should be understandable without prior knowledge of the field.
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Front page: image obtained from http://hqwide.com/video-games-super-mario-8-bit-wallpaper-20158/

Editorial

Dear reader,

The journal *Ideas, Numbers, and Knowledge (INK)* aims to create conversation on a wide variety of topics in which colleagues from all disciplines feel welcome to join. Your feedback and engagement on our articles, as well as your willingness to contribute new and inspiring topics from within your fields will ultimately bring us closer to INK's purpose, to disseminate knowledge and promote discussion.

In our previous edition, The Era of Genomics, we touched on the impact of genomics in various domains, such as the courtroom. The current issue continues that discussion through articles on biological information systems and the advent of genome-guided medicine. This edition of INK also examines a number of fascinating and controversial topics, including genetically modified organisms, redemptive capital, and the neuroscience behind mediation.

This issue's perspective article takes a look at the ever-expanding field of video-games and the new approaches being taken in their application to research. With interviews from gaming experts Adrian Lee, Carson Upton, and Becky Keener, our own Jaya Viswanathan discusses the opportunities for gamers across Vancouver, as well as the current state of research on video-game therapy. Turns out they aren't quite as bad as the media leads us to believe!

Please feel welcome to forward articles, questions, concerns, and ideas to our editorial team at any time. We look forward to hearing your voice and hope you enjoy this edition of INK!

Warm regards,

Alexandre Lussier
Editor in Chief

Content

Greetings,

On behalf of the new UBC Interdisciplinary Graduate Student Network (iGSN), it is my pleasure to inform you about our organization and the free services that we offer our members. The iGSN is a group of enthusiastic graduate students dedicated to improving the graduate student experience at UBC. Our mission is to facilitate interdisciplinary collaboration and knowledge-sharing between graduate students from different disciplines. Only through an exchange of ideas can we push the boundaries of research, obtaining new and exciting results. By providing social, recreational, and professional development opportunities that are discipline-independent and highly inclusive, we hope to accomplish this task here at UBC. The Ideas, Numbers, Knowledge (INK) journal, in particular, embodies this goal. We are proud to support the journal as it grows, and encourage you to take part in that growth through article submission or work with the INK editorial board. We hope to enhance the graduate student experience here at UBC for our members, and encourage you to join if you have not already. For more information about the iGSN, the free services we offer our members, and how to sign up for our bi-monthly newsletter, please visit our webpage at www.igsnubc.wordpress.com.

iGSN
Interdisciplinary
Graduate Student Network

Sincerely,

Kevin Mehr
iGSN President

Bytes vs. Base Pairs: Struggling to Understand and Surpass Biological Information Storage Systems

By **Rachel Edgar**

Genome Science and Technology Program, University of British Columbia

Modern biologists are faced with a growing problem — information storage — one that would never have been considered by past generations of scientists. Historically, biological sciences involve making few, small-scale observations, and then forming a conclusion. Modern biology takes the same historical methodologies and principles, but with a massive scale-up. The transition to high-throughput biology is largely due to the drop in costs, and improvements in the quality of DNA sequencing [1]. The influx of sequencing data allows scientists to examine biological systems at a depth that would not have been possible in the past. Biologists are working to find all the patterns in the vast pools of data currently available, and although biology has had millennia to develop its information storage systems, we have yet to discover the various levels of information held in biological systems.

To identify the patterns in sequencing data, computer systems have been adapted to store the complex information held by DNA strands. Sequences can be stored digitally, by translating DNA into a binary code. Each nucleotide, A, T, G and C can be represented by 2 bits of binary code (00, 01, 10, or 11). A byte of digital data is made up of 8 bits and therefore, one byte can represent a sequence of 4 base pairs (bp). The human genome is 3.2 billion bp [2], or 760 Mb of digital information. Given current technologies, 760 Mb may not seem like the awe-inspiring information capacity we would expect to encode all human life. Thus, if the human genome was stored in simple binary, I could fit 43 humans on my iPhone. However, this is not the case, and biological systems do not store information in simple binary.

Biology has engineered complex ways of increasing the information capacity of DNA beyond what is simply held in the nucleotide bases. For example, the outer surface of the DNA molecule is used as an additional level of biological information storage. Cytosine-Guanine sequences (CpG), which occur throughout the genome, can have methyl groups added to the cytosine ring (Fig. 1) [3]. The presence of a methyl group on the cytosine of a CpG site is known to affect how that section of DNA is interpreted by cellular machinery [3].

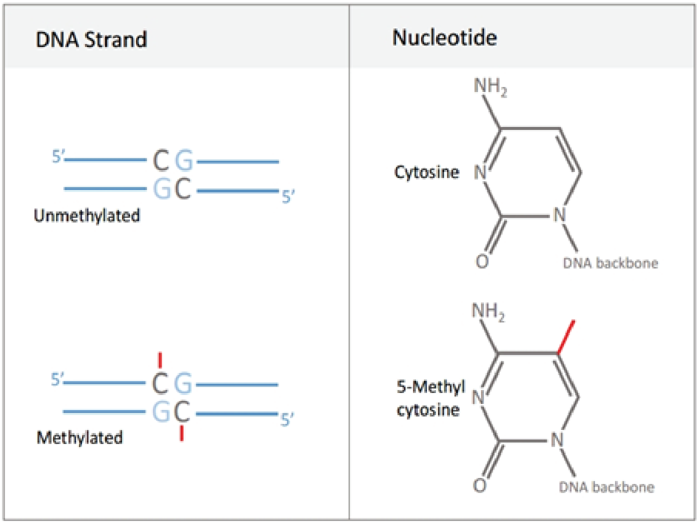

Figure 1. Methylation of DNA represented at the DNA strand (CpG) and nucleotide (cytosine) levels.

Like any DNA sequence, the DNA methylation state of a given CpG can be easily translated into a binary code. A methyl group can be bound or unbound to the cytosine in a CpG (0 or 1, respectively). The most popular technology currently used to measure human methylation is the Infinium® HumanMethylation450 BeadChip, which measures methylation at 485,577 CpG sites in the human genome.[1] These 485,577 CpG sites represent 56 Mb of digital information. But again, translating biological information to binary is an over simplification. The location of the CpG site in the genome, the state of the surrounding CpG sites, and the cell type influence how the on/off methylation signal at a given CpG is interpreted [4].

The true amount of information encoded by DNA methylation is clearly greater than 56 Mb, especially considering the observed influence of DNA methylation in biology. Mice require DNA methylation for healthy development, and do not develop when DNA methylation systems are eliminated [5]. DNA methylation has also been shown to be highly variable, with complex and subtle effects on human cancer [6]. The influence of methylation on human behaviour and brain function, however, is one of the most complex levels of information storage by methylation. DNA methylation in the brain has well documented links to developmental and neurodegenerative disorders [7], but the connections are so complex, that it is almost indecipherable exactly how DNA methylation effects brain function.

DNA methylation is one example by which biology has increased information storage, beyond the nucleotide sequence. In addition to DNA methylation, chromatin state, transcription factor binding and small RNAs all expand the information held in the human genome. The processes biology has developed to store information have allowed human complexity to evolve, but now challenge human computer systems. Biologists, bioinformaticians, and computer scientists will continue struggling to decode, store, analyze and understand all the levels of information held in biological systems. Despite this, scientists are working simultaneously to understand, and match or exceed the information storage capabilities of biological systems with computer systems. Although evolution has had millennia to master information storage systems, let's hope it doesn't take us that long.

1 http://res.illumina.com/documents/products/datasheets/datasheet_humanmethylation450.pdf

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Genetically Modified Organisms (GMOs) – Demons or Saviors?

By **Kate Pankowska**

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From an economic perspective, efficiency and profitability are the most important factors. Many agricultural economists see GMOs as a technological solution, which could potentially ensure higher crop outputs with lower labour inputs, thus yielding an increase in food production under minimalized costs. Given the growth of global population in need of nourishment [1], along with volatile climate conditions impeding crop reliability [2], this vision of GMOs could justify them to be considered as miracles.[1]

Global Panacea

If GMOs were in fact able to guarantee higher efficiency in food production, it is likely that many global food shortage problems could be solved. An increase in higher-yielding crops will guarantee more supply of staple commodities (e.g., corn) and, hence, decrease food prices due to cheaper inputs in food production. Consequently, developed countries could reduce financial transfers for food security aid to developing countries. Instead of cohorts of aid workers sent to Africa or Asia to fight the consequences of food shortages, the inhabitants of developing regions could receive improved seeds that were genetically modified to thrive in their region's specific climatic conditions and resist local pests [3]. Consequently the number of starving and undernourished people in the world would decrease, making the internal food production in these countries less dependent on food from aid schemes delivered by developed regions. Properly nourished people, especially better-fed children, translate into more cognitively proficient populace, hence more educated adults that are likely to turn into better citizens and leaders [4]. However, the provision of such genetically improved seeds, even if they are able to ensure a non-trivial increase in production efficiency, will not guarantee that the world hunger problem would disappear entirely. There are other important obstacles associated with countries' internal — and frequently imperfect — redistribution policies. After all, many developing countries have problems stemming from poorly developed laws and corrupted government infrastructure [5].

To Benefit Everybody

GMOs could also be useful in developed countries where food production efficiency is decreasing especially due to soil erosion, linked to extensive agricultural production and pesticides use. Certain types of genetically improved seeds could be implemented in the production of biofuels (e.g., genetically modified algae). Creating tree varieties that grow faster would result in more time-efficient harvests of building materials and could also be useful in the carbon sequestration efforts ("CO2 catching" scheme). Greater efficiency in terms of meat production could be achieved through genetically enhanced animals or fish. This could translate into provision of a more efficient animal protein supply that could satisfy a growing demand coming from both developed and emerging economies.

1 The author has consciously chosen to discuss only a part of GMOs story and decided to concentrate on agro-economic aspects on the continents of North and South America. Author is aware that there are many other aspects (health, environment etc.) that are associated with GMOs. Such aspects have been consciously omitted due to limited space for this article.

The Other side of the Coin

Unfortunately, as of today, such an idyllic picture of GMOs is not realistic. There are several problems associated with the introduction of GMOs on a large scale [6]. The biggest one seems to be associated with lack of clarity on how efficient GMOs actually are when introduced in the large-scale agricultural production. It is unclear if GMOs will actually prove to be a lower-cost technological solution [7]. One of the main problems is related to economics. There is a concern that a relatively small number of biotechnological companies control much of a global seed supply. Another issue comes from the methods that they use in order to execute their patent laws. Currently, the biggest acting companies in biotechnology are giants like Monsanto, DuPont and Syngenta. These companies use their strong market position to secure patents for their technologies. These actions are permissible because these companies meticulously exploit loopholes in the law to influence politicians (a practice widely used in lobbying) in order to achieve favourable policies [8].[2] They are creating a monopolistic position in the market and, from an economic point of view, this is rather disturbing [7].

The Monopoly for Genes

The basic micro-economic theory proves that the aforementioned behaviour of biotechnological giants can be translated into higher prices for their technological novelties. In addition, it is not entirely clear if crops achieved from seeds improved in this manner will be able to make farmers better off. After all, farmers not only have to buy seeds each time they plant but they also need to apply specific pesticides (e.g., Roundup®) so these improved seeds grow properly. According to binding contractual agreements, farmers cannot save their own seeds to plant next year and have to buy them each time they want to sow. This undoubtedly raises costs of production, unless crop outputs are able to leverage it. Farmers' efforts to oppose such *status quo* usually end up in the law courts where biotechnology giants have cohorts of lawyers ready to prove patent infringements. An example of such situation comes from a famous case of the Canadian farmer from Saskatchewan, Percy Schmeiser, who was accused by Monsanto of canola patent infringement [9]. A large number of farmers on the North American continent claim that their crop outputs from improved seeds were not higher than conventional seeds. In addition, once they start planting GMO seeds, it would be nearly impossible for them to revert to conventional farming methods, since the neighbouring farms yielding GMO crops would pose a risk of contamination (seeds self-sowing).

Fertile Ground

Problems with GMOs do not end at the US-Mexican border but also stretch to Argentina. Latin American countries are bombarded with marketing campaigns prepared by biotechnological giants. The most GMO-fertile ground seems to be in Argentina, where GMOs have found a very compliant political environment, especially under the current president Cristina Fernández de Kirchner. President Kirchner can frequently be spotted in press conferences with Monsanto's leaflets, agitating for large-scale implementation of their technologies.[3] The main road from San Salvador de Jujuy to Cordoba looks like a peculiar exhibition of Monsanto's latest achievements. Fields of soybeans stretch along both sides of the eight-hour-long bus route.[4] They are tightly gated and precisely marked with Monsanto's specified seed patent number. Field access is granted to Monsanto employees only. New soy crops are being planted, as ripened soy is being collected on the other side of the road. The soil seems to work around the clock, with no time being wasted. The picture of this agricultural Klondike is additionally enriched with omnipresent silos used for soy storage that seem to outnumber the quantity of other buildings in the area. Along the road there are numerous signboards that advertise the newest mechanical tools and machines necessary for extensive agricultural production. Judging by

2 Also see 'The World According to Monsanto' directed by Marie-Monique Robin.

3 See, e.g., www.youtube.com/watch?v=j10ClQSHSHM

4 Described observations are based on author's research trip to Argentina in early April 2013. Author travelled by bus from Bolivia-Argentina border (Villazon-La Quicaca) to the city of Mendoza.

the number of signboards, dealers of agricultural equipment have also found a profitable market in this area. Such landscapes stretch until the border to Mendoza, Argentina's famous wine producing province. At the border between the provinces of Cordoba and Mendoza, all vehicles have to go through a peculiar quarantine (wheels cleaning). This procedure is carefully implemented, likely to avoid the risk of contaminating precious wine producing soils.

Agro-economic Dilemma

The topic of GMOs opened a debate in agricultural economics. The Solow-type growth theory [10] would suggest the utilization of GMOs potentially beneficial because it could likely bring improved efficiency and profitability, which could solve many burning world food problems. On the other hand, common sense would suggest the necessity of a wider analysis, perhaps one extending beyond just economic theory of the entire GMO phenomenon. There is a risk that rushed and under-analyzed decisions in this matter can potentially be harmful. It seems that only a wide-scale, multidisciplinary cost-benefit analysis of GMOs is able to give realistic and accurate answers.

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THE AGE OF GENOME-GUIDED MEDICINE

By **Olena Morozova**

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The sequences of our genomes determine what we look like and what genetic diseases we might develop in the future. Recent advances in DNA sequencing technologies have allowed for more rapid and cost-effective decoding of human genomes than previously possible. Once the interpretation of genomic data becomes routine, it can be imaginable that genome sequences of an increasing number of patients will be available to clinicians. This article discusses the rise of genome-guided medicine and touches on the challenges associated with this new development in medical science.

THE SEQUENCING OF HUMAN GENOME

The information necessary to make and sustain all life forms on Earth, including humans, is specified by their genomes. Even though genomes of related organisms are similar, each organism has a unique genome sequence that serves as the fingerprint of the organism's individuality and natural history. The first human genome sequence was determined as part of the Human Genome Project, an international initiative headed by the National Institutes of Health National Human Genome Research Institute [1]. In parallel with this government-funded initiative, the private company Celera Corporation initiated its own effort, which concluded near the time of the completion of the public effort [2]. The public effort took over a decade to complete (1990-2003), and it cost 3 billion dollars to determine the identity of approximately 3 billion letters of the human genetic code. The effort resulted in the creation of a reference human genome sequence that enabled subsequent studies on how differences in the genetic code contribute to human diseases and physical attributes.

The first human genome sequencing initiatives underscored the need for more cost-effective sequencing methods that would allow for routine sequencing of human genomes. Determining the genetic code of groups of individuals is essential for understanding correlations between genetic sequences and physical traits (e.g., susceptibility to a disease) found in different populations of people. This realization as well as the availability of the human reference genome sequence drove the development of the so-called "next-generation" sequencing technologies that hit the market in 2005 [3]. These technologies parallelized the sequencing process, and as a result, the cost of genome sequencing dropped from millions to thousands of dollars per individual genome. Most recently it is approaching the $1,000 per human genome price tag that is no longer cost-prohibitive to individual investigators or health care providers [4].

Sequencing throughput has been increasing by over five-fold each year, while computational throughput is said to follow the Moore's Law and improves two-fold every 18-24 months [5]. In line with the Moore's Law-defying advances in sequencing, the last five years have seen an explosion of genome sequence data generated from healthy and diseased individuals. It was estimated that at the end of 2011, over 30,000 individual genomes had been sequenced in laboratories around the world [6]. The research bottleneck in the field of genome science has therefore shifted from data generation to data interpretation, highlighting the need for better computational tools and more resources to analyze vast amounts of DNA sequence data. The discipline that is tasked with the interpretation of genome sequence data is bioinformatics.

DNA SEQUENCING IN THE MEDICAL FIELD

Over the past few years, DNA sequencing has been applied to the study of a growing number of genetic diseases, including cancers. Several recent breakthroughs in cancer research can be attributed to the development of new sequencing methods and their application to cohorts of cancer patients. For instance, the work at the Genome Sciences Centre (GSC) in Vancouver showed that a large proportion of non-Hodgkin lymphoma cases were associated with mutations in a class of genes involved in the packaging of DNA in the cell [7]. Another study at the GSC revealed that mutations in a gene called FOXL2 occurred in almost all cases of granulosa cell tumours, a specific type of ovarian cancer [8]. Beyond cancers, DNA sequencing has been fruitful at identifying the underlying causes of rare genetic diseases, such as Miller Syndrome [9]. Even though these discoveries do not provide immediate cures or treatments for the diseases, follow-up studies may lead to the development of new therapies and/or diagnostic or prognostic tests based on these initial observations.

In addition to studies that contribute to our understanding of the disease biology, a growing number of projects have used sequencing data to guide medical decisions. A study conducted at the GSC used genome sequencing of a rare cancer and identified a genetic feature of that cancer that could be targeted by an existing drug [10]. The treatment resulted in some improvement of the disease compared to the previous therapy. However, the patient eventually succumbed to their disease. Additional personal genome sequencing initiatives, in which genomes of terminal cancer patients are decoded with the hope of identifying treatment options are being conducted at several institutions, including the Translational Genomics Research Institute (TGen) in Phoenix, Arizona. In terms of preventative medicine, genome sequencing of healthy individuals has been used to predict the individual's risk of developing common illnesses, such as cardio-vascular diseases, diabetes or psoriasis [11].

The road ahead

Despite the promise that clinical applications of DNA sequencing hold for both patients with genetic diseases and healthy individuals, the clinical deployment of DNA sequencing is associated with challenges. In addition to the challenges with data interpretation discussed above, there are ethical issues with whole genome sequences of individuals. In particular, personal genome sequencing may reveal unpleasant and potentially unwanted results: for instance, a mutation that will lead to a disease for which there is no known cure or a genetic predisposition for a disease that runs in the family and therefore may affect the individual's children. Another commonly raised concern is the release of the individual genome data into the public domain and the availability of such data to insurance companies or employers. Given these concerns, the routine deployment of genome-guided medicine will undoubtedly involve efforts of many professionals, including scientists, medical practitioners, policy-makers, and the patients themselves.

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If you have ever played and enjoyed any video-game, you have been excited, relieved, anxious, and engrossed in the situations your avatar faces; each emotional state creating a medley of hormones in tandem with the game dynamics. This is irrespective of whether the game(s) you enjoy is the likes of FarmVille (on Facebook) or Grand Theft Auto 5 (the most popular action video-game on IMDB [www.imdb.com] with a score of 9.8/10 as of November 2013).

Video-game graphic quality has undergone a massive technological leap over the last few decades. The Atari game console released in 1977 offered action games such as combat and air-sea battle. If you grew up in the 90s, you must have heard of or played Prince of Persia (1989); the graphics used to create this game were far superior to any created previously. Fig. 1 demonstrates the evolution of video-game graphic quality over time. Today, game consoles (such as the Nintendo Wii and Sony PlayStation) come equipped with special controllers and motion sensors. Besides being incredibly sophisticated in terms of plot, today's video-games are a creative medium for expressing art; customizable to different players and levels. Fig. 2 compares different modes of action video-games such as massively multiplayer, online, and gaming console.

But how is all this relevant to *you*?

A google scholar search for "video-game" yields over 25,000 scientific articles. So, I set out to investigate the significance of the video-game industry for a graduate student in Vancouver.

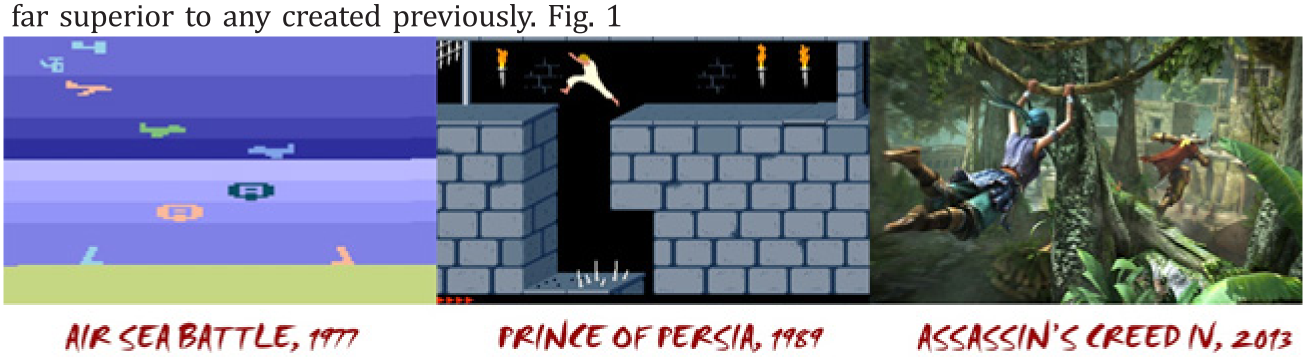

Figure 1. Evolution of video-game graphics for action video games over time. From left to right: Air-Sea Battle (Atari, Inc), Prince of Persia (Brøderbund), Assassin's Creed IV (Ubisoft). Open source 3D modelling software such as blender (www.blender.org) allows group/community creativity and further evolution of this technology.

Figure 2. Variety in action video games today, from left to right clockwise: God of War is a 3rd person action-adventure game first released in 2005 for PlayStation 2; World of Warcraft is a massively multiplayer online role-playing game released in 2004 for PC; The Brigmore Witches is the fourth game in the action-adventure series 'dishonoured' and was released in 2013 for PC, PlayStation 3 and Xbox 360; Dungeons and Dragons is a 2010 fantasy role playing video game inspired by a board game released in 1974.

In Vancouver, there are at least 7 meetup groups that serve the gaming community with an average of 475 members per group. Some of these groups cater exclusively to women interested in gaming. There are currently 5 AMS clubs at UBC dedicated to gaming. Fig. 3 shows the large number of video-game stores in Vancouver.

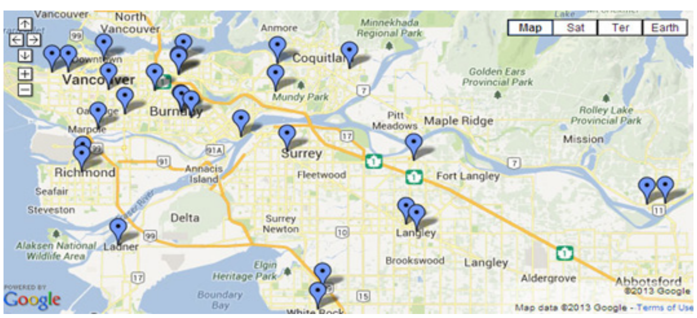

Figure 3. Screenshot of video-game stores in and around mainland Vancouver. Source: Google maps.

I also had the opportunity to learn about the gaming community in our city by speaking with gaming aficionados Adrian Lee,[1] Becky Keener,[2] and Carson Upton.[3] Carson informed me about the gaming communities based out of UBC – they are some of the biggest communities in Vancouver and include clubs for Star Craft 2 and League of Legends, a game that is particularly popular at this time. Becky was enthusiastic about local businesses that have started to cater to gamers and promote gaming, such as Storm Crow Tavern, Verace Pizzeria, and various coffee houses around the city. The EXP bar & Grill is unique, recommended by both Adrian and Becky for gamers; if you need to regenerate your HP or MP (Health Points and Magic Points, for the un-initiated), this is the place for you! Aside from putting on events like "PokéMonday Tournament!", they host launch parties for new releases, run demos, and stream live gaming competitions. It seems like *the* go-to place for geeking out on games! In addition, Vancouver is a "HOTBED of video-game development", according to Adrian Lee. He continued: "The games made here are both for the 'triple A' market (high budget, publicly traded mega corps), as well as independent small teams of two to ten developers. All these games will span various genres, sometimes creating new ones!"

To me, frankly, this is amazing. A decade ago playing video-games was considered nerdy, a social *faux pas*. Today, it is a fashionable thing to do – and rightly so. Regardless of what you might have been told as a kid about video-games being bad for your eyes, several recent studies have shown that video-games might hold the key to improving several aspects of brain function, at least in the visual domain. Playing action video-games enhances visual attention: the ability to efficiently allocate it over space, time, and number of objects [1]. What is even more promising is the finding that this increased spatial resolution of attention extends beyond the region of trained space, indicating a generalization of the effect. A lot of resources are channelled into finding more effective rehabilitation for patients via training. So far, training on video-games has been the only paradigm (out of several) where the training effects have generalized outside of the experimental parameters!!! Fig. 4 shows the category of video-games, the pace of engagement in relation to improvement in visual attention.

Video-games have also been very recently found

1 The organizer of Vancouver Gamers Group on www.meetup.com

2 The organizer of Geeks and Gamers and Vancouver World of Warcraft on www.meetup.com

3 A partner in GottaCon - comprehensive and professional gaming convention that all gamers on Vancouver Island and the surrounding areas enjoy.

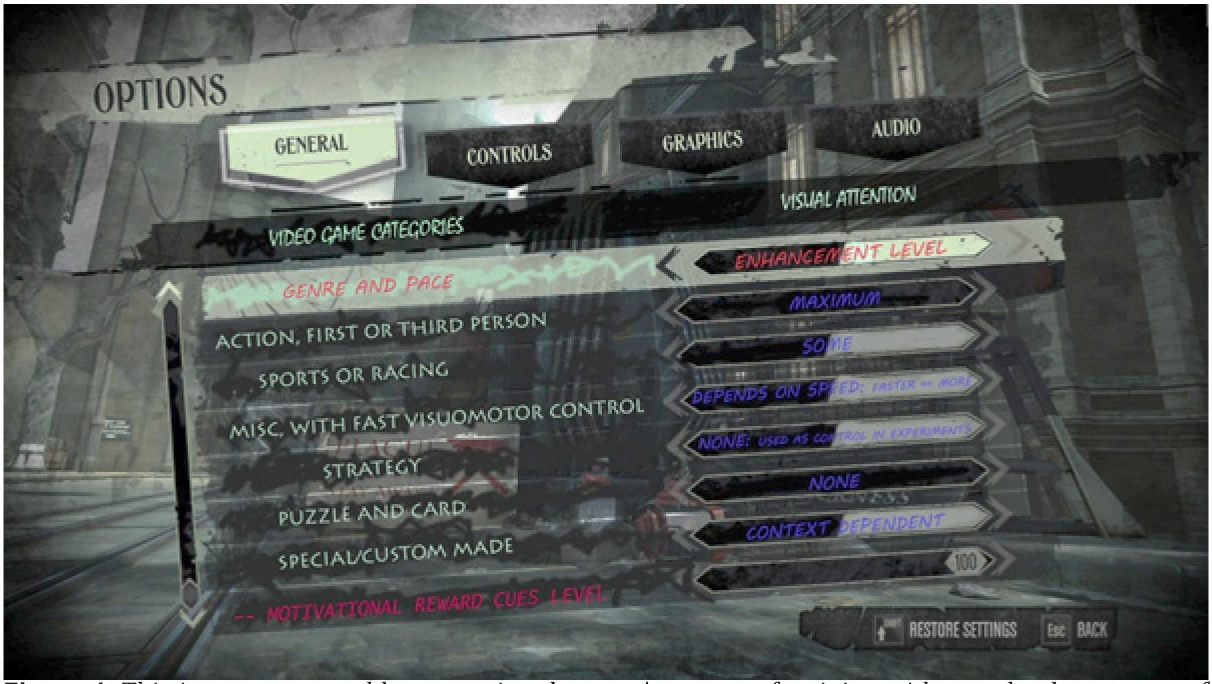

Figure 4. This is a summary table comparing the type/category of training with actual enhancement of visual attention. Speed/pace seems to be key; slower games have a smaller improvement on attention. In any game, receiving reward cues spurs learning. Figure adapted from the game Dishonored (Arkane Studios).

to influence learning in different ways, based on the type of video-game, and have been shown to improve learning in dyslexic children [2]. Researchers are using findings like these to create novel therapies. In 2012, a team of researchers and clinicians from The University of Auckland made the "popular news" circuit for creating and testing SPARX.[4] Based on Cognitive Behavioural Therapy, SPARX was designed to help adolescents overcome depression by battling negative thoughts! Adrian also recommended "The Typing of the Dead" [5],[5] a 1999 arcade game (that has been remade!) which helps to learn typing.

This is all very exciting for gamers, scientists, and game designers alike, as it opens new avenues for research, technology and medical rehab/therapeutic development. I think games like SPARX and Typing of the Dead serve as inspiration for development of more games which help improve your health and brain. Adrian says "Game design is an incredibly complex and resource intensive undertaking. Even indie games take more toil than most people will ever realize, but that does not mean that games can't teach people things and still be fun."

There is a common notion today that everything that "feels good" in the modern world is bad for you: high fructose corn syrup, risk-seeking behaviour, and alcohol consumption being prime examples. While *pathological* video gaming has been linked to increased overall impulsivity and risky decision making in young adults and children [3], in every other way, playing in moderation seems to be beneficial for your brain while feeling good. So...

Just keep playing and having fun!

4 www.sparx.org.nz/ - contains information about the research, goals, scientific publications and ways you can help this great venture.

5 http://en.wikipedia.org/wiki/The_Typing_of_the_Dead

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Redemptive Capital - An Ethnographic Look at Human-Horse Rescue Relationships

By **Tamar Scoggin McKee**

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> *"What has happened to Manny is a true definition of a crime. He had no way out or a way to change what was happening to him. Why was he discarded? Why couldn't they find a legitimate home for him? Why, when he stopped making them money, did they 'throw him away'? What makes a person lose their humanity? Their compassion? I don't understand and will never understand how this came to be."*
>
> Excerpt from Fieldwork Interview with Manny's Adopter

In 2011, while conducting multispecies ethnographic fieldwork [1] in the Bluegrass region of Kentucky, USA, I encountered many former Thoroughbred racehorses each with their own poignant and political story of rescue from slaughter once their racing careers were over. One horse's rescue story, however, stood out to me most, and offers a powerful example of the idea of "redemptive capital" that I want to illustrate here.

His racing name was Classic Order, and while he earned some money on the track in the American Midwest, he was found in a "ship to kill" pen at Ohio's Sugarcreek Livestock Auction in October of 2009. He was discovered because his rescuer could flip his upper lip and read the still-legible racing registration tattoo from The Jockey Club of North America. She then looked up the tattoo numbers in the registry to confirm his status and identity. Outfitted with this information, she appealed to the humanity of an official at Hoosier Park racetrack in Ohio who contributed 350 dollars to purchase Classic Order from the kill pen.

The forces of economic capital that shaped Classic Order's demise and subsequent rescue are already evident in just the brief introduction to his story — but what of other possible "species of capital" [2] also at work? Informed by Bourdieu's trinity of economic, cultural, and social capital and how symbolic capital mediates all three, I offer the idea of "redemptive capital" to help explore ethnographically (and provoke morally) that which makes "something" worthy of rescuing from "death" (in both the figurative and literal sense). Though this idea was first inspired by my fieldwork with horses rescued from slaughter, redemptive capital can also be explored in more than just animal subjects such as humans, material culture, spaces, places, and other salient "things" threatened with loss.

Returning to Classic Order's story, the redemptive capital initially at work for him in that Sugarcreek kill pen was a combination of traits: the fact he was a registered Thoroughbred racehorse who possessed a tattoo that could identify him, and that he had the behavioural wherewithal to stand still so that his rescuer could get a good look at his tattoo. Had his tattoo been illegible because he was too unmanageable to permit his rescuer to read it, Classic Order would have met with a very different fate.

Redemptive capital is thus first the elements — in this case the horse's identity and behaviour — considered too valuable to discard. This valuation is innately cultural and historically specific, even in its economic forms [3-4]. As such, what is seen as worthy capital in a horse — a valourized breed, a calm disposition – is already culturally meaningful and powerful enough to inspire action. However, worthiness is also realized and transformed in the midst of action or practice.

After being pulled from the kill pen, Classic Order was taken in by the Thoroughbred Retirement Foundation (TRF), one of the largest equine rescue organizations in North America. He was placed with its "Second Chances" program at the Putnamville Correctional Institution in Indiana, where the inmates learn how to care for horses. In time, Classic Order became known as "Lucky" — perhaps because he had been saved from the thousand-plus mile journey to slaughter in either Canada or Mexico. In March 2011, he was scouted out by another program run by the TRF, the Maker's Mark Secretariat Center (MMSC). Based in Lexington, Kentucky, MMSC specializes in re-schooling Thoroughbred ex-racehorses for adoption as riding horses. I tagged along on this trip as part of my fieldwork, and witnessed Lucky and the rest of his herd shucking through early spring mud in woolly winter coats, bellies distended by hay.

In this condition, Lucky did not look much like a re-schooling prospect, but more redemptive capital emerged when he was evaluated for how ride-able he might be. As an inmate led him through walk and trot gaits, MMSC staff observed and took notes. Based on what they saw in Lucky — no injuries; good, balanced movement; attractive body conformation underneath the muddy, woolly coat — they chose him for the program. This evaluation speaks to how redemptive capital can be subjective and targeted by the audience in addition to embodied and dynamic in the subject. Let us now consider how truly dynamic it can be.

Three weeks later, Lucky arrived at MMSC and I followed his transformation from a feral horse, as some at MMSC described him, to an adoptable, show-ready, off-track Thoroughbred. As part of his transformation, Lucky's barn name changed to "Odie", and he stood obediently once again as his mane was pulled, tail banged, and body consistently washed with medicated shampoo to rid him of the rain rot that had colonized his chestnut coat. This feral horse was being further redeemed — if only aesthetically at first — into the identity of a show horse.

This new status became more apparent when, five months later, I attended a horse show where Odie, now renamed "Manny" (a nickname for Emmanuel), participated in his first competition as a show horse. During his Dressage test I watched as Manny elegantly curled his neck, veins threading across his now amber-glowing chestnut coat, giving a performance worthy of a fourth place ribbon. Such is evidence that in addition to the makeover of his outward appearance, Manny had also transformed fundamentally at the site of what Tim Ingold [5] might call his equine "being-in-the-world". Instead of comporting himself as a failed racehorse or pasture-retired horse, Manny demonstrated the ability to "become" [6-7] the horse desired by his rescuers. As such, Manny's redemptive capital was further cultivated at the site of not just his body, but his agency, as "the precise role granted to non-humans" that is beyond "natural causality" according to Latour's Actor-Network-Theory [9].

In this short story of how Classic Order was discarded only to be redeemed as Manny, I have offered the idea of redemptive capital to think of the various cultural dimensions that go into rescuing a life from death. I have demonstrated here how the components of redemptive capital are culturally valued aspects of life that are embodied, constantly evolving, and largely subjective depending on the situation. In essence, the concept of redemptive capital helps raise significant moral and ethical questions when it appears that such qualities could simply be "thrown away" without a second thought, just like Classic Order.

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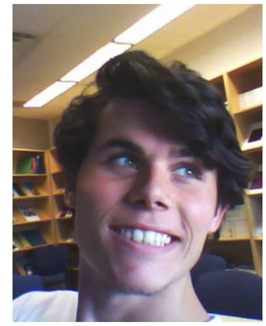
How Meditation Changes the Brain for the Better



By **Dano Morrison**

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In 2003, Tenzin Gyatso, the 14th Dalai Lama, presided over a small group of neuroscientists at the Massachusetts Institute of Technology (MIT), announcing his desire for Western science to study Eastern contemplative practice. Since that landmark dialogue, an entire field of research has arisen, hoping to understand the neuroscience behind meditation. This research has created a new appreciation for meditation as a way to change the brain for the better: improving cognition, well-being, and treating mental illness.

Meditation and Functional Imaging

To understand what happens in the brain during meditation, scientists turned to brain imaging techniques such as functional magnetic resonance imaging (fMRI), which detects changes in cerebral blood flow to identify which regions of the brain are active during a specific task. This research revealed that meditation is associated with increased activity in areas of the brain that control attention and self-awareness and decreased activity in areas associated with mind-wandering and emotional reactivity [1]. Three areas of the brain have been consistently associated with increased activity during meditation: the dorsolateral prefrontal cortex (DLPFC), the anterior cingulate cortex (ACC) and the insula [2-3]. These areas are believed to mediate executive control of attention, sustained concentration, and self-awareness, respectively [4-5]. Conversely, the brain's default mode network, so named because it is active when the mind is not focused on anything in particular, is silenced during meditation [6]. The default mode network is thought to be involved in daydreaming, narrative thought, and may underlie the self-focused, ruminative thinking that is a key feature of depression [7].

These findings parallel the traditional Buddhist understanding of meditation. For thousands of years, Buddhists have meditated by focusing their attention on a single target, such as the breath, the body, or a mantra. This practice is described by the Buddhist scriptures as a way to enter a state of awareness without judgment, where the mind is free from distraction and desire [8]. Interestingly, these features are consistent with what happens in the brain of experienced meditators upon practice: more attention and less distraction.

Structural and Cognitive Changes Associated with Meditation

In 2005, a groundbreaking study examined the brains of experienced meditators with structural magnetic resonance imaging, using magnetism to identify the size of different regions of the brain. Surprisingly, several areas in the prefrontal cortex and insula were found to be larger in meditators than in non-meditators of the same age, sex and level of education [9]. Although this experiment could not rule out the possibility that prior differences in brain volume may have contributed to an individual's likelihood to adopt a years-long meditation practice, this study provided strong evidence linking meditation with long-lasting changes in brain structure.

Since this original finding, several other studies have continued to find differences in brain volume related to long-term meditation practice [10-16]. These effects are small — a mean difference of 20 cubic millimeters in one study — but occur in areas associated with attention and self-awareness [13]. Interestingly the brains of meditators also show greater white matter connectivity and levels of cortical gyrification; features that suggest meditators may be able to process information faster [12, 17]. Furthermore, meditators appear to suffer less from age-related brain degeneration [10, 14].

However, there are inconsistencies within the research. No effects have been yet been observed in the DLPFC or ACC [10]. Furthermore, findings from some studies have failed to be replicated [11, 13]. It is unclear to what extent these discrepancies are due to differences in study design, as the few studies that have been performed all differ either in sample characteristics (cross-sectional vs. intervention), type of meditation practice, or method of quantifying brain volume.

Nevertheless, researchers have also begun to collect evidence for cognitive benefits associated with meditation. Several studies have shown that meditation experience correlates with more accurate, flexible, control of attention across a number of different tasks [14, 18-19]. There is also research suggesting that meditators display a higher level of empathy and are better able to regulate their emotions [20-21].

Meditation and Plasticity

Though there is more work to be done before a causal relationship between meditation and these brain changes can be confirmed, a story is emerging: frequent activation of areas involved in attention and self-awareness during meditation increases the volume of these areas and improves their function.

Mechanistically, there is very little we understand about how this story would work. How does frequent activity alter brain structure? What changes at the cellular level are responsible for these increases in volume and how do they contribute to improved function? Basic research into the neuroplasticity, the cellular mechanisms behind the brain's ability to change, may one day allow us to answer these questions.

Information processing in the brain occurs through an intricate network of neurons, connected by millions of tree-like, branching axons and dendrites. Critical to the brain's ability to adapt are the changes that occur in this network, where neurons receive and process incoming information. Although their general structure is stable, dendrites are covered with thousands of dendritic spines, small projections that continually grow and retract, appear and disappear, as they seek out other neurons with which to form synapses. Information flowing through these synapses guides the process of growth and retraction, such that meaningful connections are stabilized and unnecessary connections are eliminated [22]. High levels of neural activity lead to the stabilization of new spines, growth of new synapses, and increases in the size of existing synapses. These structural changes are thought to underlie the creation of new patterns of activity and the refinement of existing neural circuits [23].

The brain consists of billions of neurons and trillions of synapses, so it is conceivable that the growth of new spines and synapses, triggered in certain brain regions by meditation, could lead to measurable increases in brain volume [24]. This idea may also explain why volume changes are observed in only some areas, because depending on the nature of the region's neural circuitry, increases in efficiency might be more closely related to a refinement process involving the elimination of unnecessary spines and synapses.

At this point, there can only be speculation about how meditation may physically shape the brain. There are many ways through which frequent neural activity could lead to increased brain volume. For example, the growth of new blood vessels or glia, neuron-supporting cells that continually reproduce in the brain, may also contribute to changes in the size of certain brain regions [25-26].

In summary, there is a growing body of research that suggests meditation can have profound effects on the brain. However, there remains much to be studied about the physiological changes that may underlie these effects. The most recent review of research on meditation as a clinical treatment concludes that it is "an effective treatment for a variety of psychological problems, and is especially effective for reducing anxiety, depression, and stress" [27]. Further understanding of the psychological and physiological effects of meditation will allow us to harness the powerful benefits of this practice. Insights into the science behind meditation may also allow us to one day improve upon these ancient Eastern techniques, which some may argue are in need of updating after thousands of years.

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