The Epigenetic Roots of Emotional Intelligence

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ABSTRACT

Emotional intelligence was defined by the American Dialectic Society in 1995 as one of the new terms often used in popular science. Few other scientific theses have engaged the attention of theorists and researchers for as long as has the dynamically expanding conceptual framework of emotional intelligence. Perceived in many ways – as a cognitive ability, as social competence, and a personality trait that is genetically inherited – emotional intelligence continues to intrigue people. It finds broad social applications in numerous fields – science, education, medicine, organizational development, economics, politics, business, and interpersonal relationships. The interpretation of the term "emotional intelligence" makes it possible to formulate different definitions and models for research, but academics usually build their theses on the processes of emotional regulation. As emotions are a consequence of the perception of the environment and the interpretation of perceived information, it is clear that these processes are linked with epigenetics. Epigenetics paves the way toward a precise understanding of intelligence, and particularly of emotional intelligence. The roots and fine mechanisms of its manifestation lie in the intimate connection between our genes and the environment.

Keywords: emotional intelligence, genetics, epigenetics, psychosomatics, brain, stress

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> ***Intelligence is the ability to adapt to change.***
>
> Stephen Hawking

Today, when we apply the words of Stephen Hawking to humans, we might at first say that they seem to contradict the words of Darwin, who long ago wrote: "...not the strongest of the species survive, nor the most intelligent. It is the one that is most adaptable to change."

Sounds partially contradictory, right?! Whether adaptation generally means being the most *intelligent*, or the most *adaptable*, or both, seems confounding. At the same time, it is undoubtedly challenging to come to a precise definition of the term when refering to all the great minds who have discussed this subject. Then again, we should not forget that a hundred years have passed between the origin of these two concepts. Things have changed dramatically in the science of biology and the meaning and wisdom of human adaptation have been redefined.

In past centuries, the idea of adaptation was predominant, but today, we know that the issue is generally somewhat different. The contemporary definition of adaptation is that it is a function of our intelligence and of our ability to sense changes in the environment and react effectively and quickly enough. These capacities are undeniably impossible without rapid changes in our genes. However, any change in the genes sounds frightening. How were we able to preserve the identity of *Homo Sapiens* for such a long period if our genes were not undergoing constant change? Well, the answer lies in our ability to change through modulating the work of our genes in their adaptation to the surrounding environment. It is this modulating work that makes our

adaptation to the fast speed of today's world possible. It requires a redefinition and a deep understanding of the intricate interactions between our genetics and our environment. Part of this redefinition is our understanding of human intelligence which drives our progress and development as human beings.

Intelligence, Knowledge, and Ideas – the Salt of Life

Intelligence is one of the concepts we have tried, but always failed, to completely define. Studies on intelligence date back to the 20th century, when Dr. Spearman defined human intelligence in a sophisticated way (Spearman, 1961). He unambiguously proved that intelligence could be understood as a general ability permeating all tasks and abilities unique to each intellectual undertaking. In modern terms, and although this does not cover its entire meaning, intelligence is the ability to acquire and apply knowledge and skills (Sternberg, 2012). Since then, different domains of knowledge and skills have developed that apply this knowledge. If indeed there are various aspects and dimensions of intelligence, this seems logical.

Interestingly, when people have certain learning impairments, their brain compensates by focusing on other areas, or by heightening their ability to learn in different ways. Therefore, we now speak of eight distinct types of intelligence: visual-spatial, linguistic-verbal, logical-mathematical, bodily-kinesthetic, musical, inter- and intrapersonal, and naturalistic (Gardner, 1987), thus eliminating the unified nature of the term intelligence. Things are further complicated when these eight types of intelligence seem to coincide in different individuals, or differ most unexpectedly in identical twins (Toccaceli *et al.*, 2018). This stands as clear proof of the complicated and far from easily understood nature of intelligence.

The Biological Roots of Intelligence

Human intelligence is rooted in its underlying brain function, and scientists speculate that individual differences in brain activity are reflected in individual corresponding behavior. This intricacy further increases when we consider how the brain is formed. Just imagine; we all begin life from a single cell – the fertilized oocyte, which after a subsequent number of divisions, forms the fetus with specialized cells, tissues, and organs, all containing the same bundle of genes forming matching genomes (Hussain, 2012). During embryonic development, the process that drives cell specialization is not mutagenesis, i.e. changes in the genes and DNA, but rather the biochemical modifications that happen on the genes. This biochemical make-up of the genome makes genes silent or active, regulates their activity, and thus leads to cell specialization in brain, heart, muscle cell types, and many others (Waddington, 1963).

The brain is indeed the most complex structure in the human body since cell specialization alone appears inadequate to form a complex organism, and since these cells must function in a coordinated manner. Perhaps nowhere is this so deceptive as in the human brain. The brain's complex structure is built by 100 billion neurons that integrate to form more than 100 trillion connections (Semendeferi *et al.*, 2011). This specialization, along with synchronization, allows our brain to not only manage basic physiologic functions such as breathing, but also to generate the complex thoughts and feelings that make each of us unique. On the other hand, let's not forget that all 100 billion neuronal cells share the same genome and operate differently depending on their specialization, in addition to which the most important brain and physiological functions are driven through this specialization (Georgieva, Staneva, & Miloshev, 2016; Nicoglou & Merlin, 2017). Epigenetics drives this process and is controlled by specific biochemical modifications that arrange genes in active and inactive states, depending on the stimuli that come from the surrounding environment. Recent data suggest that although genetic and environmental factors simultaneously contribute to cognitive test performance, intelligence malleability is a result of modifications of gene expression via epigenetic mechanisms like DNA methylation, histone post-translational modifications, small non-coding RNAs, and the overall organization of chromatin – all of which rely on and are triggered by environmental factors, such as changes in the educational system, overall exposure to stress, traumatic experience, nutrition, and poverty (Georgieva and Miloshev, 2020; Flynn, 1985; Lester *et al.*, 2011).

Specifically, Flynn, in a series of studies demonstrated that due to changes in the everyday life of people in the decades following World War II, the leap in the general IQ and overall cognitive abilities of successive generations was so evident that it could not be explained by change in the underlying genetics (Flynn, 1985; Trahan, Stuebing, Fletcher, & Hiscock, 2014). This obvious jump in the intelligence scores of postwar generations was called the "Flynn effect" by other authors (Trahan *et al.*, 2014). It was argued that various environmental factors, such as the educational system, technological progress, improved nutrition, and lifestyle, all impacted this phenomenon. Bratsberg and Rogeberg published an interesting study (Bratsberg & Rogeberg, 2018) constructively addressing the Flynn effect. The authors used the administrative register data of Norwegian male birth cohorts to look at three decades of information on family relationships and cognitive ability. They were able to unambiguously show that the increase, the turning point, and decline of the Flynn effect can be recovered from within-family variation in intelligence scores. This establishes that large changes in the average cohort intelligence reflect environmental factors, rather than changes in the parental genetic composition, and that these environmental factors act specifically via changes in neurobiological systems relevant to cog-

nition (Kaminski *et al.*, 2018). Possible neurobiological factors that mediate this effect, and link genotype with complex traits like cognition, are epigenetic markers, including DNA methylation, the cortical architecture of the brain, and its functioning. Precisely these adaptability markers might contribute to the "missing heritability" that is present in many studies on intelligence and the genetic variations among individuals.

The term "missing heritability" of human intelligence appeared a couple of decades ago when the sequencing of the human genome allowed scientists to discern changes in the overall physiology and general psychological traits of humans without major differences in the genetics (Tauer, 1992). Around that time, a major search for the missing genetic link in human performance began. A couple of authors determined that in human intelligence, about 20% of genetic variations in certain genes are respectively responsible for brain functioning and structure (Savage *et al.*, 2017; Sniekers & Stringer, 2017), whereas twin studies suggested a 50-70% genetic predisposition to high IQ (Polderman *et al.*, 2015). Although these studies oppose nature versus nurture, they are a major step forward in understanding the neurobiology of intelligence, as well as genetically- and epigenetically-associated neurological and neuropsychiatric traits. Recent genome-wide meta-analyses have identified 205 genomic loci and 1,016 genes associated and strongly expressed in the brain, specifically in striatal medium spiny neurons and hippocampal pyramidal neurons (Davies *et al.*, 2016; Savage *et al.*, 2017), thus revealing genetics at the forefront of shaping the human brain and its manifestations, like intelligence and adaptability. Nonetheless, though the genetic studies were solid, even these authors argue that the above discoveries are too thin to definitively explain individual differences in the intelligence of almost genetically identical humans, and the jump between their IQ values in time, and in response to different surrounding stimuli due to their lifestyles.

Recently, an interesting study was published by Kaminski *et al.* (Kaminski *et al.*, 2018) focused on genes involved in dopamine-based neurotransmission and their link with IQ scores and cognitive abilities. Dopamine is a hormone and neurotransmitter that plays several important roles in the brain and body (Blandini *et al.*, 2001; Salehpour & Hamblin, 2020), and is linked with the brain's reward system, thereby modulating drive and motivation. Moreover, any impairment in its metabolism leads to severe neurodegenerative diseases, like Alzheimer's and Parkinson's. These findings by Kaminski *et al.* show a link between epigenetic changes in dopamine neurotransmission and an individual's IQ test performance. Epigenetic modifications can silence the dopamine receptor gene, leading to reduced signal transmission and fewer dopamine receptors being activated. This, in turn, was associated with lower IQ test results. Stress and dopamine production have both previously been linked to cognitive performance (Nieoullon, 2002). Now, environmentally-induced gene activity can be added to the list of factors known to influence IQ scores.

Genes and the Environment – The Essence of Epigenetics

The essence of life is driven by the complex interactions among genes and the environment, in other words, between genetics and epigenetics. It has to be stressed that epigenetics plays a crucial role during development. It shapes the way the genome works in response to all kinds of changes in the surrounding environment (Siggens & Ekwall, 2014). Although epigenetic significance was observed in live creatures in the 20th century (Waddington, 1963), epigenetics emerged as a real science approximately only a dozen years ago (Allis, Jenuwein, & Reinberg, 2007). But if we go even further back, say 2,500 years, and look at the writings of Hippocrates (specifically, "On Air, Water, and Places"), we find that even then he defined, albeit indirectly, the term epigenetics. There, Hippocrates skillfully formulates and explains three main reasons why we get sick. According to him, the first is due to nutrition, the second to the pollutants that reach us from the air and water, and the third to accidental events, including fatigue, stress, and accidental injuries.

Today the modern definition of epigenetics is "a study of mitotically and/or meiotically heritable changes in gene function that cannot be explained by changes in DNA" (Wolffe, 1998; Wolffe & Matzke, 1999). Through epigenetic mechanisms, cells integrate environmental conditions to fine-tune gene expression levels. Thus, it is now believed that epigenetic mechanisms drive biological responses to a plethora of different stimuli, like metabolic, stressful, social, and other issues arising from the surrounding environment. For example, central metabolites like folic acid are the substrates for enzymes that catalyze the deposition of covalent modifications on histones, DNA, and RNA – thus regulating the manifestation of our genes, and hence our adaptation.

Defining Emotional Intelligence

The topic of emotional intelligence (EI) is still very dynamically debated and has long engaged scientists. The term "emotional intelligence" was first mentioned in the 1960s in Professor Leuner's works (Leuner, 1966). Many scientific publications followed, in which attempts were made to define emotional intelligence as a set of abilities, competencies, personality traits, or some combination thereof. Regardless of the ideological and methodological differences of the research teams, it can be more broadly deduced that emotional intelligence is each person's knowledge of how they perceive, process, facilitate thinking, and manage emotions – both their own and those of others, in a specific environment. These processes of emotional regulation

are a combination of personality traits or a constructed scheme of abilities, e.g., for adaptation, communication, motivation, decision-making, etc. The idea that the structure of emotional intelligence contains the ability to understand oneself and others was introduced by Howard Gardner. In his book *The Theory of Multiple Intelligences*, published in 1983, he brilliantly put forth his idea that there are multiple intelligences. He argues that there is interpersonal intelligence (the ability to understand other people's expectations, motivations, and desires) and intrapersonal intelligence (the ability to understand oneself, to understand and evaluate one's feelings and motivation), and that they are integral parts of emotional intelligence. This idea was revolutionary for its time, because it drew attention to the fact that the individual perceives and builds relationships with the environment based on his specific abilities. The book was reviewed by Friedman (Friedman, 1985), who paved the way for the term emotional intelligence in the best way. Later on, professors John Mayer (Stanford University) and Peter Salovey (Yale University) coined the term "emotional intelligence" in 1990 (Mayer, DiPaolo, & Salovey, 1990), and formally defined it: "Emotional Intelligence includes the ability to engage in sophisticated information processing about one's own and others' emotions and the ability to use this information as a guide to thinking and behavior. That is, individuals high in emotional intelligence pay attention to, use, understand, and manage emotions, and these skills serve adaptive functions that potentially benefit themselves and others." It was Daniel Goleman, a journalist, who popularized the concept of emotional intelligence by bringing it into the public arena. Goleman published *Emotional Intelligence* in 1995 (Goleman, 1995), in which he wondered why some people who are blessed with superior intellectual abilities seem to fail in life, while others with more moderate gifts succeed. Like Mayer and Salovey, Goleman hints at the genetic nature of emotional intelligence, but does not prove it. He stresses that IQ contributes about 20% to factors that determine life success, which leaves 80% to other factors, i.e., to the environment. Data from the research of Adrian Fernham and Constantin Petrides are presented on the genetic origin of emotional intelligence (Petrides, Furnham, & Martin, 2004). According to these authors, emotional intelligence is a combination of inherited personal characteristics. Moreover, the authors hypothesized that men would have higher IQ but lower EI than women, and that participants, regardless of gender, would rate their fathers as higher on IQ but lower on EI than their mothers. The results confirmed these hypotheses, supporting the view that people perceive psychometric intelligence as a primarily masculine attribute in contrast with emotional intelligence, which they perceive as a primarily feminine attribute. The results also showed that the intensity of the stereotypical perception of EI as a feminine attribute diminished when the authors asked participants to estimate their scores on a range of specific EI facets, instead of providing a direct overall self-estimate. And although there are no major genetic differences between men and women, still the genetic and epigenetic variations paved the road for endless discussions on the subtle meaning of the role of heritability in intelligence – particularly its emotional component.

The Epigenetic Roots of Emotional Intelligence

Epigenetics is reflected in all areas of our existence. Therefore, when we talk about emotional intelligence, we take seriously the important role of epigenetics in our ability to perceive, evaluate, and manage our emotions. Epigenetics also affects our ability to understand the emotions of others in different situations. While emotional intelligence is a relatively new field of study in psychology, the influence of genetics and epigenetics on it is a much younger field of study in biology and medicine. As a result, and thanks to the technology and research advances in this area, we now know that anger, fear, empathy, euphoria, and, in general, all the emotions that accompany our daily lives in one way or another, depend on our genetics and epigenetics.

In 2018, the prestigious journal *Nature* published a large-scale study on the relationship between emotional intelligence and genetics. The aim was to prove or disprove the relationship between the genetics we inherit and our emotional intelligence – in particular, our ability to experience and empathize (Warrier *et al.*, 2018). The study included scientists from the University of Cambridge, UK, the Pasteur Institute and the Université Paris Diderot in France, as well as the genetic research company 23andMe (https://www.23andme.com). A total of 46,861 people were studied. More than 10 million different gene variants were tested. The focus of the research was on empathy as one of the most important components of emotional intelligence. What scientists found was that only 10% of a person's ability to show empathy is due to genetic characteristics. The remaining 90% is not encoded by genes but depends on environment and lifestyle – on an individual's epigenetics. If we go back to the famous comparison of the brain with an iceberg, we can understand that the visible 10% of the iceberg in our brain depends on the genetics transmitted to us, while the other 90% is invisible, deeply immersed in our subconscious or unmanifest emotions, feelings, and intellect.

Emotional intelligence determines the quality of people's communication, and their level of resilience and adaptability. Depending on their emotional intelligence aptitude, people can motivate themselves without waiting for external stimuli, and they can successfully regulate their emotions by reacting without aggression or impulsivity. By using the full range of personal characteristics, skills, abilities, beliefs, convictions, acceptance or rejection, thought patterns and emotions, we are responsible for the quality of our relationship with the environment. Given that everything around us af-

fects the work of our genes, emotional intelligence is the direct bridge and the reflection to all changes in the surrounding environment and its impact on our genetics. Therefore, all mindful choices for improvement of our lifestyles, and thus our psychological comfort, will favorably influence our emotional intelligence and our cognitive abilities. In addition, modern techniques such as body psychotherapy act as influential epigenetic modulations of the comfort of our physiology and psychology and stand as positive examples of how careful modulation of our environment holds the potential to influence the activity in our genes.

The human brain is enigmatic, which is why the interest in it and in the human psyche are great. This is especially true lately, when many academics are actively working in the field of artificial intelligence. Scientists fear that artificial intelligence could replace the human brain when it comes to routine and non-emotional activities, but it cannot express emotions and feelings – especially empathy. For example, again in 2016, the University of Cambridge opened a center to study the effects of artificial intelligence on humanity (https://www.cam.ac.uk/research/news/the-future-of-intelligence-cambridge-university-launches-new-centre-to-study-ai-and-the-future-of). At its inauguration, Professor Margaret Bowden, who has been researching artificial intelligence for more than 50 years, said she was not worried about the development of the technology, but stressed that she had not found a way, in her decades of research, by which artificial intelligence can replace the human in activities requiring compassion or emotional intelligence (Boden, 2015).

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Associate Professor Milena Georgieva, PhD, Molecular Genetics Lab, Institute of Molecular Biology, BAS. Milena is an associate professor in molecular biology. Her current work investigates the interplay between DNA and the environment during normal development, aging, and age-associated disease. As a specialist in molecular biology, genetics, and epigenetics, Milena believes that in modern biomedicine we now very clearly distinguish between the time before and after the Human Genome Project. The time "after" not only marks the beginning of the new millennium, but also highlights the beginning of a turning point in modern medicine, where the handwriting of our genes and the specificity of our DNA are studied in the light of epigenetics. As a zealous communicator of science, Milena strives to present trends in modern science in accessible and interesting language.

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REFERENCES

Allis, C. D., Jenuwein, T., & Reinberg, D. (2007). *Epigenetics.* Cold Spring Harbor Laboratory Press.

Blandini, F., Fancellu, R., Martignoni, E., Mangiagalli, A., Pacchetti, C., Samuele, A., & Nappi, G. (2001). Plasma homocysteine and l-dopa metabolism in patients with Parkinson disease. *Clin Chem*, 47(6), 1102-1104.

Boden, M. A. (2015). Creativity and A Life. *Artificial Life*, 21(3), 354-365. doi:10.1162/ARTL_a_00176

Bratsberg, B., & Rogeberg, O. (2018). Flynn effect and its reversal are both environmentally caused. *Proceedings of the National Academy of Sciences*, 115(26), 6674-6678. doi:10.1073/pnas.1718793115

Davies, G., Marioni, R. E., Liewald, D. C., Hill, W. D., Hagenaars, S. P., Harris, S. E., . . . Deary, I. J. (2016). Genome-wide association study of cognitive functions and educational attainment in UK Biobank (N=112 151). *Molecular Psychiatry*, 21(6), 758-767. doi:10.1038/mp.2016.45

Flynn, J. R. (1985). Wechsler intelligence tests: do we really have a criterion of mental retardation? *American Journal of Mental Deficiency*, 90(3), 236-244.

Friedman, P. (1985). Book Reviews: Gardner, H. (1983). Frames of mind: The theory of multiple intelligences. New York: Basic Books. *Gifted Child Quarterly*, 29(2), 94-95. doi:10.1177/001698628502900212

Gardner, H. (1987). The theory of multiple intelligences. *Annals of Dyslexia*, 37(1), 19-35. doi:10.1007/bf02648057

Georgieva, M., Staneva, D., & Miloshev, G. (2016). Epigenetic significance of chromatin organization during cellular aging and organismal lifespan. In D. Hollar (Ed.), *Epigenetics, the environment, and children's health across lifespans* (pp. 21-66). Cham: Springer International Publishing.

Georgieva, M. and Miloshev, G., (2020). The magic of epigenetics – recipes for healthier life. *International Body Psychotherapy Journal*, (19)1, Spring/Summer 2020: 107-115.

Goleman, D. (1995). *Emotional intelligence.* New York: Bantam Books.

Hussain, N. (2012). Epigenetic influences that modulate infant growth, development, and disease. *Antioxidants & Redox Signaling*, 17(2), 224-236. doi:10.1089/ars.2011.4484

Kaminski, J. A., Schlagenhauf, F., Rapp, M., Awasthi, S., Ruggeri, B., Deserno, L., . . . Desrivières, S. (2018). Epigenetic variance in dopamine D2 receptor: a marker of IQ malleability? *Translational Psychiatry*, 8(1), 169. doi:10.1038/s41398-018-0222-7

Lester, B. M., Tronick, E., Nestler, E., Abel, T., Kosofsky, B., Kuzawa, C. W., . . . Wood, M. A. (2011). Behavioral epigenetics. *Annals of the New York Academy of Sciences*, 1226, 14-33. doi:10.1111/j.1749-6632.2011.06037.x

Leuner, B. (1966). [Emotional intelligence and emancipation. A psychodynamic study on women]. *Praxis der Kinderpsychologie und Kinderpsychiatrie*, 15(6), 196-203.

Mayer, J. D., DiPaolo, M., & Salovey, P. (1990). Perceiving affective content in ambiguous visual stimuli: a component of emotional intelligence. *Journal of Personality Assessment*, 54(3-4), 772-781. doi:10.1080/00223891.1990.9674037

Nicoglou, A., & Merlin, F. (2017). Epigenetics: A way to bridge the gap between biological fields. *Studies in History and Philosophy of Biological and Biomedical Sciences*, 66, 73-82. doi:10.1016/j.shpsc.2017.10.002

Nieoullon, A. (2002). Dopamine and the regulation of cognition and attention. *Progress in Neurobiology*, 67(1), 53-83. doi:10.1016/s0301-0082(02)00011-4

Petrides, K. V., Furnham, A., & Martin, G. N. (2004). Estimates of emotional and psychometric intelligence: evidence for gender-based stereotypes. *Journal of Social Psychology*, 144(2), 149-162. doi:10.3200/socp.144.2.149-162

Polderman, T. J., Benyamin, B., de Leeuw, C. A., Sullivan, P. F., van Bochoven, A., Visscher, P. M., & Posthuma, D. (2015). Meta-analysis of the heritability of human traits based on fifty years of twin studies. *Nature Genetics*, 47(7), 702-709. doi:10.1038/ng.3285

Salehpour, F., & Hamblin, M. R. (2020). Photobiomodulation for Parkinson's disease in animal models: A systematic review. *Biomolecules*, 10(4), 610. doi:10.3390/biom10040610

Savage, J. E., Jansen, P. R., Stringer, S., Watanabe, K., Bryois, J., de Leeuw, C. A., . . . Posthuma, D. (2017). GWAS meta-analysis (N=279,930) identifies new genes and functional links to intelligence. *bioRxiv*, 184853. doi:10.1101/184853

Semendeferi, K., Teffer, K., Buxhoeveden, D. P., Park, M. S., Bludau, S., Amunts, K., . . . Buckwalter, J. (2011). Spatial organization of neurons in the frontal pole sets humans apart from great apes. *Cerebral Cortex*, 21(7), 1485-1497. doi:10.1093/cercor/bhq191

Siggens, L., & Ekwall, K. (2014). Epigenetics, chromatin and genome organization: recent advances from the ENCODE project. *Journal of Internal Medicine,* 276(3), 201-214. doi:10.1111/joim.12231

Sniekers, S., & Stringer, S. (2017). Genome-wide association meta-analysis of 78,308 individuals identifies new loci and genes influencing human intelligence. *Nature Genetics,* 49(7), 1107-1112. doi.org/10.1038/ng.3869

Spearman, C. (1961). The abilities of man. In J. J. E. P. Jenkins, Donald G. (Ed.), *Studies in individual differences: The search for intelligence* (pp. 241-266): East Norwalk, CT: Appleton-Century-Crofts.

Sternberg, R. J. (2012). Intelligence. *Dialogues in clinical neuroscience,* 14(1), 19-27.

Tauer, C. A. (1992). The human significance of the genome project. *Midwest Medical Ethics,* 8(1), 3-12.

Toccaceli, V., Fagnani, C., Eisenberg, N., Alessandri, G., Vitale, A., & Stazi, M. A. (2018). Adult empathy: Possible gender differences in gene-environment architecture for cognitive and emotional components in a large italian twin sample. *Twin Research and Human Genetics,* 21(3), 214-226. doi:10.1017/thg.2018.19

Trahan, L. H., Stuebing, K. K., Fletcher, J. M., & Hiscock, M. (2014). The Flynn effect: A meta-analysis. *Psychological Bulletin,* 140(5), 1332-1360. doi:10.1037/a0037173

Waddington, C. H. (1963). Ultrastructure aspects of cellular differentiation. *Symposia of the Society for Experimental Biology,* 17, 85-97.

Warrier, V., Toro, R., Chakrabarti, B., Børglum, A. D., Grove, J., Hinds, D. A., . . . the 23andMe Research Team (2018). Genome-wide analyses of self-reported empathy: correlations with autism, schizophrenia, and anorexia nervosa. *Translational Psychiatry,* 8(1), 35. doi.org/10.1038/s41398-017-0082-6

Wolffe, A. P. (1998). Epigenetics. Introduction. *Novartis Foundation Symposium,* 214, 1-5.

Wolffe, A. P., & Matzke, M. A. (1999). Epigenetics: regulation through repression. *Science,* 286(5439), 481-486.

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https://www.cam.ac.uk/research/news/the-future-of-intelligence-cambridge-university-launches-new-centre-to-study-ai-and-the-future-of

https://www.23andme.com