Understanding Personality Development Through Genetic and Environmental Contributions

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Personality development arises from the ongoing interactions between genetic predispositions and environmental experiences throughout a person's life. This literature review synthesizes findings from published behavioral genetic studies, longitudinal twin and adoption research, molecular analyses, and environmental psychology to interpret how genetic, environmental, and gene-environment interaction processes contribute to the stability and transformation of personality traits. Evidence from twin studies and meta-analyses confirms that traits such as Extraversion, Neuroticism, and Conscientiousness are moderately to highly heritable. Nonetheless, this heritability remains unexplained at the molecular level, a gap known as the "missing heritability" problem. In contrast, non-shared environments, including unique life events and personal relationships, are found to be more influential than shared family environments in shaping personality development, particularly during critical developmental periods. The review also explores gene-environment interactions, including how personality traits mediate stress perception and how genetic predispositions influence the selection and interpretation of environmental contexts. Despite evident advancements, the field is plagued by an overreliance on Western populations, broad and imprecise environmental constructs, and insufficient integration of epigenetic discoveries. This review concludes that advancing a comprehensive understanding of personality requires integrative, developmentally sensitive, and culturally inclusive research that connects behavioral genetics, environmental psychology, and emerging genomic technologies.

Keywords: Personality development, behavioral genetics, non-shared environment, gene-environment interaction, epigenetics

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For decades, psychologists, geneticists, and social scientists have been intrigued by the investigation of personality development and stability, particularly in gaining insights into the origins and evolution of personality traits. Determining the course of these processes provides practical insights into the individual differences observed in behavior, cognition, and emotional regulation throughout a person's life. The Five-Factor Model (FFM), developed by Costa and McCrae (1992), is one of the most empirically supported frameworks for characterizing personality traits. The FFM defines individual personality using five broad and stable dimensions: Neuroticism, Extraversion, Openness to Experience, Agreeableness, and Conscientiousness. Neuroticism refers to emotional instability and a predisposition to psychological distress, such as anxiety, sadness, and vulnerability. Extraversion represents traits associated with sociability, assertiveness, and a tendency toward experiencing positive emotions. Openness to Experience involves active imagination, aesthetic sensitivity, and intellectual curiosity. Agreeableness reflects interpersonal tendencies such as trust, altruism, and empathy, whereas Conscientiousness concerns self-discipline, organization, and goal-directed behaviors. These dimensions provide a generalizable framework for understanding typical personality functioning and its implications for behavior across the lifespan (Costa & McCrae, 1992). General findings reveal that the prominence of Extraversion, Conscientiousness, and Neuroticism tend to predict effects on one's mental health, relationships, education, and employment (Briley & Tucker-Drob, 2014). These traits structure how individuals react to their environments and engage with the world around them. Still, identifying the bases that contribute to the stability and change of personality traits remains a continuous investigation. Over several decades, empirical studies have consistently demonstrated that both genetic and environmental factors significantly influence personality. However, the relative contributions of these influences, and more significantly, how they interact, remain the subject of ongoing investigation, debate, and theoretical refinement.

Behavioral genetic research within twin, adoption, and family studies consistently shows evidence that personality traits are 40% to 60% heritable, suggesting that genetic factors account for a substantial proportion of individual differences (Power

& Pluess, 2015). Increasing evidence also suggests that personality is not a fixed concept; it evolves in response to environmental demands, developmental transitions, and life experiences (Bleidorn et al., 2016). These results facilitated the transition from dichotomous "nature versus nurture" discussions to more integrative models exploring how genetic markers and environmental factors influence trait development. Additionally, advancements in molecular genetics and epigenetics have presented new methodological possibilities for exploring the biological foundations of personality while introducing new questions about the intricacy of gene-environment interactions. Despite technological advancements, challenges persist: specific genetic variants linked to personality traits remain inaccessible, environmental constructs are often vaguely defined, and the field continues to rely heavily on research from White, Educated, Industrialized, Rich, and Democratic (WEIRD) populations, thereby limiting the generalizability of previous discoveries.

This review synthesizes prior research on the genetic and environmental impacts on the development and stability of personality, focusing on how these elements interact across time and context. The review is structured in four parts. First, it examines empirical evidence for the genetic contributions to personality stability, highlighting both additive and non-additive genetic effects. Second, it examines the role of environmental influences, particularly non-shared environments, in shaping personality development during critical life transitions. Third, it investigates gene-environment interactions and correlations, which help explain how genetic predispositions guide environmental exposure and interpretation. Finally, it critiques current methodological limitations and outlines emerging trends and future directions for advancing the field. This integrative approach clarifies how personality traits are maintained and changed and encourages future research in this field to become more specialized. It identifies approaches for future research that more accurately reflect the complexity of human development, offering a blueprint for further exploration and discovery.

Genetic Contributions

Genetic influences are paramount in the stability of personality traits, with an increasing number of findings supporting the conclusion that inherited predispositions guide consistent behavior patterns. Bouchard's (1993) combined findings, based on Minnesotan monozygotic twins reared apart, found notable similarities in personality profiles despite differences in upbringing. These similarities suggest that shared genes, rather than shared environments, are more strongly associated with trait similarities. This evidence suggests that personality is partially influenced by genetic makeup. This finding is also apparent in the later work of Briley and Tucker-Drob (2014), who synthesized data from longitudinal twin and adoption studies, reporting that genetic effects account for 40% to 50% of the variance in the FFM traits. Furthermore, their research suggests that as one's age increases, the genetic influence on personality traits becomes increasingly pronounced, indicating that the consolidation of personality in adulthood is partially genetically determined (Briley & Tucker-Drob, 2014). Their findings also revealed the influence of non-additive genetic effects, such as gene-gene interactions, highlighting the depth and intricacy of the genetic predisposition behind trait development.

Plomin et al. (2016) expanded this framework by identifying the top ten replicated findings in behavioral genetics, affirming that nearly all psychological traits are heritable and that shared environmental effects—often presumed to be influential—are surprisingly minimal. However, despite this convergence of evidence, a significant gap remains between heritability estimates derived from twin studies and the limited number of specific genetic variants identified through molecular genetic approaches. Researchers term this discrepancy the "missing heritability" problem, which challenges the ability to specify the biological mechanisms that express genetic influence. Bratko, Butković, and Vukasović Hlupić (2017) further supported the heritability estimates in previous twin studies. Likewise, their meta-analysis emphasized the methodological limitations of relying heavily on classical twin designs, such as potential overestimations of genetic influence due to unmeasured confounds (Bratko, Butković, & Vukasović Hlupić, 2017).

While the chosen literature provides vigorous support for the idea that genetic factors contribute significantly to the stability of personality traits, these studies largely remain correlational in nature. Often, these results cannot establish causal relationships necessary to reveal underlying mechanisms, support predictions, and enable effective interventions by establishing direct relationships between variables. Like much of psychology research, it relies predominantly on Western samples, which limits generalizability to more diverse populations. These gaps highlight the pressing need for additional research.

Environmental Contributions

As researchers seek to explain the variance in personality not attributed to genetic factors, they focus on the environmental influences on personality development. Increasing empirical evidence suggests that non-shared environmental experiences, which are unique to the individual and not shared among siblings or twins, play a particularly significant role in personality development across the lifespan. These influences include distinct interpersonal relationships, occupational demands, individual responses to life events, and other experiences embedded within specific social, cultural, and environmental contexts that shape personality in dynamic and enduring ways. One of the most robust empirical examinations of environmental effects was by Hopwood et al. (2011), who utilized a three-wave longitudinal twin design within the Minnesota Twin Family Study. The

Multidimensional Personality Questionnaire (MPQ) assesses four broad dimensions: Negative Emotionality (NEM), reflecting emotional instability and stress reactivity; Agentic Positive Emotionality (PEM-A), associated with ambition and social dominance; Communal Positive Emotionality (PEM-C), capturing warmth and empathy; and Constraint (CON), indicating self-control and risk avoidance. (Hopwood et al., 2011). Their results revealed pronounced changes in NEM and CON between late adolescence and early adulthood, followed by trait stabilization into the late twenties. This aligns with the maturity principle, which posits that individuals develop emotional stability and self-regulation as they assume adult roles and responsibilities. This finding, therefore, further reinforces the aforementioned results, as lived experiences uniquely shape personality development.

In addition, Su and Yu (2023) provided a recent synthesis of environmental influences by examining the interplay of social context and personality through twin studies. They argued that environmental effects are distinct across individuals and vary in prominence depending on developmental stage, sociocultural setting, and interaction with genetic predispositions. Their review emphasized that proximal environmental factors, such as parenting quality, peer relationships, educational experiences, and romantic partnerships, can have a profound impact during sensitive periods of personality development. Their findings demonstrate that environmental exposures can reinforce or impair dispositional tendencies, depending on how they align or conflict with an individual's inherent traits (Su & Yu, 2023). Despite these promising insights, one of the most persistent limitations in environmental research is the inability to control genetic confounding sufficiently. Many studies rely on general population samples and do not employ genetically sensitive designs (e.g., twin, sibling, or adoption studies), ultimately threatening confidence in attributing causality to environmental effects. For instance, a classic suggestive gene-environment correlation between harsh parenting and child aggression may not be purely environmental but rather reflect genetically influenced child behaviors that evoke specific parental responses.

Furthermore, while non-shared environments are increasingly acknowledged as central to personality differentiation, shared environmental influences remain under-theorized and inconsistently addressed. Most behavioral genetic studies report minimal shared environmental contributions to adult personality; however, this conclusion may stem from methodological limitations, such as age restrictions in samples, broad operationalization of environmental variables, or lack of longitudinal tracking of early-life contexts. Some researchers argue that shared environments may have delayed or indirect effects, influencing trajectories in ways that only manifest under specific conditions, such as during stress or transition. Additionally, cultural context is a critical yet often overlooked dimension in environmental personality research. The overwhelming reliance on WEIRD (Western, Educated, Industrialized, Rich, and Democratic) populations limits the generalizability of findings, as it overlooks how environmental influences—such as collectivist vs. individualist values, economic inequality, or exposure to conflict—may interact with personality development in non-Western societies. Culturally embedded environmental variables, such as collectivist versus individualist social structures, intergenerational value transmission, or culturally sanctioned expressions of emotion, may shape trait trajectories in ways that have yet to be adequately theorized or tested. Cultural norms shape the content and structure of environments, modulating the desirability and expression of traits such as Conscientiousness or Neuroticism, thereby influencing developmental trajectories in complex ways.

Lastly, environmental research in personality psychology often suffers from conceptual ambiguity. The term "environment" is frequently used in broad or vague ways, incorporating everything from neighborhood safety to parenting style to national GDP, without clear theoretical frameworks to distinguish their mechanisms of influence. Without specificity, the ability to design effective interventions or identify modifiable risk factors is severely limited. Future studies must prioritize precision in environmental measurement, incorporate gene-by-environment interaction modeling, and engage in longitudinal, cross-cultural designs to clarify how environments shape, reinforce, or constrain personality traits across time. Doing so would improve theoretical understanding and enhance practical applications, such as tailoring educational approaches, workplace supports, or clinical treatments to individuals' environmental contexts.

Gene-Environment Interactions

Recent studies of gene-environment interactions (G×E) provide a substantial framework for understanding how biological and environmental influences jointly contribute to the development and expression of personality traits. Unlike models that treat genetic and environmental influences as additive and independent, G×E models emphasize the reciprocal and dynamic relations, wherein genetic predispositions can influence exposure to and interpretation of environmental experiences. Conversely, environments can moderate the expression of genetic traits. Using twin data, the empirical work by Luo et al. (2015) provides a compelling example of G×E dynamics in personality. The researchers investigated the relationship between personality traits and stress perception, revealing that approximately 70% of the variance in stress reactivity could be due to genetic factors (Luo et al., 2015). However, personality traits moderated this genetic influence: individuals high in Neuroticism perceived events as more threatening and responded with greater distress, whereas those high in Conscientiousness employed more adaptive coping mechanisms, such as planning and self-regulation (Luo et al., 2015). These findings depict how environmental challenges, such as perceived stress, do not affect individuals uniformly; rather, the impact of environmental exposure is contingent on individual dispositional profiles, supporting the Diathesis-Stress model in personality psychology.

Theorists such as Plomin and colleagues (2016) have traced how genetic traits influence responses to the environment and the types of environments individuals encounter through genotype-environment correlations (rGE). The interactions include passive rGE (e.g., a child inherits both a genetic predisposition for extraversion and an extraverted home environment), evocative rGE (e.g., a temperamentally difficult child evokes more punitive parenting), and active rGE (e.g., a sensation-seeking adolescent gravitates toward risky peer groups). Jaffee and Price (2008) argued that such rGEs complicate causal claims in environmental psychology by demonstrating that individuals' genetic dispositions partly influence the distribution of environments rather than randomly assigned environments. This insight holds relevance in the study of psychiatric risk and maladaptive personality traits, where the observed effects of harsh parenting, peer rejection, or socioeconomic adversity may reflect a bidirectional interaction between inherited tendencies and environmental feedback (Jaffee & Price, 2008). Their research advocates using genetically informed designs, such as adoption or longitudinal discordant twin studies, to control confounding factors and accurately determine the environmental contributions to various outcomes (Jaffee & Price, 2008).

Despite advances in G×E research, several critical gaps persist. Firstly, few studies simultaneously measure both genetic susceptibility and environmental exposure with sufficient granularity to detect interaction effects, particularly in naturalistic settings (Bratko et al., 2017). Many G×E models rely on simplistic environmental proxies (e.g., "life stress" or "parenting quality") that fail to capture the complexity, timing, and intensity of real-world experiences (Bratko et al., 2017). Additionally, the longitudinal stability of G×E effects remain underexplored. While traits like Neuroticism and Conscientiousness have moderated environmental sensitivity, it remains unclear whether these interactions persist across time or vary depending on the developmental stage (Bratko et al., 2017). For instance, adolescents may be more susceptible to environmental modulation of genetic traits than older adults due to heightened neuroplasticity and identity formation processes. Another limitation is that most G×E studies rely on samples from WEIRD societies, potentially overlooking the interaction between culturally specific environments and genetic propensities (Bratko et al., 2017). For example, Assertiveness or Emotional expressiveness may generate different environmental responses and, thus, different developmental trajectories depending on societal standards and expectations. Moreover, current G×E research has yet to fully incorporate epigenetic mechanisms that may mediate the environmental influence on gene expression. Early tribulation, chronic stress, and social enrichment are correlated with epigenetic modifications, such as DNA methylation, which can activate or silence gene expression without altering the DNA sequence (Bratko et al., 2017). These changes may help explain how environmental inputs become biologically embedded, exerting lasting influence on personality traits. Nevertheless, the integration of epigenetic data with behavioral G×E models remain limited by methodological complexity and the high cost of collecting genomic data. Future research must move beyond twin correlations and single-environment predictors toward multivariate, time-sensitive, and culturally diverse designs that integrate molecular genetics, behavioral data, and life-history context (Bratko et al., 2017). Doing so would advance the field's capacity to define how nature and nurture interact to influence trait levels and shape the developmental pathways through which personality unfolds across the lifespan.

Critiques and Emerging Trends in Research

Despite significant strides in understanding the biological and environmental foundations of personality, research in this domain still faces several conceptual and methodological challenges that hinder the advancement of theory and application. One of the most persistent and widely discussed issues is the "missing heritability" problem. This phenomenon entails that heritability estimates derived from behavioral genetic studies (typically 40–60% for personality traits) vastly exceed the proportion of variance explained by specific genetic variants identified through genome-wide association studies (GWAS), which has substantial implications. For example, while twin studies consistently demonstrate moderate to high heritability for traits such as Extraversion and Conscientiousness (Briley & Tucker-Drob, 2014; Bouchard, 1993), GWAS findings have thus far identified only small-effect loci that cumulatively explain a fraction of this heritability (Plomin et al., 2016). This discrepancy highlights the complexity of the genetic architecture of personality, suggesting that most traits are polygenic, influenced by thousands of variants with individually negligible effects and that non-additive effects, such as gene-gene interactions or epistasis, may contribute more than previously estimated. Researchers increasingly turn to polygenic risk scores, machine learning techniques, and deep sequencing to close this gap. Nonetheless, these approaches remain in the early stages and require large, diverse, and longitudinal datasets for validation.

In addition to this molecular-level uncertainty, ongoing methodological critiques have long served as a cornerstone of heritability research, targeting the over-reliance on twin studies. Critics argue that classical twin designs may inflate genetic estimates by assuming equal environments for monozygotic and dizygotic twins and failing to account for gene-environment correlation (rGE) effects. While informative, twin studies alone cannot resolve questions about causality or biological mechanisms, necessitating the incorporation of complementary designs such as adoption studies, molecular genetic data, and within-family longitudinal models. For instance, adoption studies allow researchers to compare the similarity of adopted children to their adoptive and biological parents, providing insights into the relative contributions of genetics and environment to personality. Moreover, many of the most-cited twin studies, including the Minnesota Twin Family Study, are now decades old and

composed of predominantly white, middle-class, Western samples, raising concerns about their relevance to contemporary, multicultural populations. As Bratko et al. (2017) note, findings based on such samples may not generalize to individuals from different cultural backgrounds or socioeconomic conditions, in which environmental variability and contextual pressures are more pronounced—for instance, individuals growing up in unstable political environments, low-income households, or collectivist cultures may experience different developmental influences on personality. The underrepresentation of global and non-WEIRD populations also limits the field's capacity to assess how culturally specific environments interact with biological predispositions to shape personality traits.

Another major critique involves the conceptual vagueness and inconsistent operationalization of environmental constructs in personality research. Terms such as "life experiences," "parenting," or "stressful environments" are often broadly defined, making it difficult to pinpoint which environmental mechanisms exert meaningful influence on personality development. Additionally, temporal aspects of environmental exposure—such as the duration, frequency, and developmental timing—are frequently ignored or oversimplified. Researchers risk mischaracterizing how experiences form traits over time if they do not consider the timing, duration, and intensity of individuals' exposure to specific environments. These limitations become even more severe since many studies do not distinguish between shared and non-shared environmental influences or incorporate designs that can isolate their respective contributions. As a result, conclusions concerning environmental impacts are often correlational and susceptible to reverse causation or gene-environment confounding.

In response to these critiques, emerging trends in personality research are shifting toward more integrative and multidimensional approaches. These include advancements in genomic technologies, such as whole-genome sequencing, which enables a comprehensive analysis of an individual's genetic makeup, and polygenic score modelling, which aggregates the effects of multiple genetic variants to predict an individual's risk for a particular trait or disorder. The incorporation of epigenetic data enables the study of how environmental factors influence gene expression, as well as neuroimaging and ecological momentary assessment (EMA), to examine personality in context and in real time. Continuing to increase cross-disciplinary collaborations among behavioral geneticists, developmental psychologists, and computational scientists increases the chances of designing more comprehensive models that reflect the plasticity, complexity, and cultural embeddedness of personality development. Additionally, researchers are now emphasizing developmental timing more, exploring how transitions such as adolescence, emerging adulthood, or parenthood serve as critical windows during which genetic and environmental influences may reorganize and recalibrate personality trajectories. Collectively, these trends reflect a growing recognition that the field must evolve beyond simple heritability estimates and static trait models toward dynamic, context-sensitive frameworks that can capture the reciprocity of multiple variables over time.

Future Directions

Future research on personality development must progress beyond isolated investigations of genetic or environmental influence toward integrative, interdisciplinary models that better capture the complexity of human development. One of the most imperative areas for advancement is addressing the missing heritability problem, which continues to cast uncertainty on the molecular foundations of personality. Although twin and family studies consistently estimate moderate heritability for traits such as Extraversion, Neuroticism, and Conscientiousness (Briley & Tucker-Drob, 2014; Plomin et al., 2016), molecular genetic research has struggled to identify specific variants that collectively account for this variance. However, the potential of advanced genomic tools, including genome-wide association studies (GWAS) with much larger and more diverse samples, whole-genome sequencing, and polygenic scoring methods capable of aggregating the effects of thousands of loci, is immense. These tools can bridge the gap in our understanding of personality. In doing so, researchers will move closer to mapping the complete genetic architecture of personality and elucidating how it interacts with contextual factors over time. Additionally, identifying genes is only one piece of the puzzle; future work must also integrate functional analyses of these genes to determine how they influence neural systems, hormonal pathways, and psychological processes that underlie dispositional behavior.

Equally critical is the need to precisely characterize environmental influences, doing so in ways that account for developmental timing, intensity, and duration. Current environmental assessments often lack granularity, relying on broad proxies like "stress" or "parenting quality" that obscure more specific mechanisms of action. A more thorough investigation of non-shared environmental factors is urgently needed, as they continue to explain a significant portion of the variance in personality that remains unaccounted for by genetics. Importantly, these investigations should incorporate genetically sensitive designs (e.g., discordant twin studies, Mendelian randomization) to minimize confounding and better estimate causal relationships. Given that environmental exposures are not static, future research should explore how life transitions, such as entering the workforce, becoming a parent, or experiencing trauma, may trigger periods of increased plasticity during which personality traits are more malleable and susceptible to change.

In parallel, the integration of epigenetic research into personality science holds promise for explaining how environmental influences become biologically embedded. Mechanisms such as DNA methylation, histone modification, and non-coding RNA expression offer pathways by which environmental exposures can regulate gene expression without altering the underlying

epigenetic research remains underutilized in mainstream personality psychology due to logistical and analytic challenges. Future studies must prioritize collecting longitudinal epigenetic data and invest in developing analytic frameworks that can connect gene expression patterns with trait development across time and contexts. Furthermore, research should examine whether epigenetic changes moderate the effects of gene-environment interactions, potentially amplifying or mitigating dispositional tendencies in response to environmental input.

Finally, there is a growing imperative to ensure that future personality research is culturally inclusive, developmentally sensitive, and translationally relevant. The overrepresentation of WEIRD populations in genetic and psychological studies limits both the generalizability of findings and the equity of their applications. Future research should include diverse samples across socioeconomic, racial, and cultural contexts to capture human variability and identify population-specific patterns of personality development. Future studies must also account for the influence of culturally structured environments on trait development, recognizing that expressions of personality may vary significantly depending on cultural norms, values, and emotional display rules. Additionally, as the science of personality becomes increasingly biologically informed, researchers must remain vigilant to the ethical implications, including genetic privacy, risk prediction, and stigmatization. Integrating ethical foresight with methodological innovation is crucial, as this will ensure that personality science contributes to theoretical advancement and the development of personalized interventions, therapeutic frameworks, and educational supports that improve well-being across the lifespan. In summary, the future of personality research lies in embracing its multidimensional nature, which encompasses biology, context, time, and culture, while continually refining its tools to reflect the complexity of the human condition.

Conclusion

Personality development is a dynamic, lifelong interaction between genetic predispositions and environmental contexts. The literature reviewed here provides robust evidence that personality traits such as Extraversion, Neuroticism, and Conscientiousness are moderately to highly heritable. Genetic factors significantly contribute to both trait stability and individual differences. Studies using classical twin designs, longitudinal meta-analyses, and molecular techniques have consistently affirmed the central role of heritability, revealing the nuanced and polygenic nature of genetic influence. These findings do not imply a fixed personality but rather a biological foundation that is continuously shaped and reshaped through dynamic environmental interactions.

Environmental research has revealed that non-shared experiences—those uniquely encountered by individuals even within the same family—significantly influence personality development, particularly during sensitive life transitions such as adolescence and early adulthood. While shared environments seem to have minimal long-term impact, this does not diminish the importance of context. Instead, it underscores the urgent need for more precise and developmentally informed models of environmental influence. Furthermore, gene-environment interactions and correlations provide a critical framework for understanding how dispositions and experiences co-evolve. Individuals do not passively receive environments; they actively shape, interpret, and select them in ways that reflect and reinforce their genetic makeup.

Despite these advances, several conceptual and methodological gaps remain. The missing heritability problem continues to challenge molecular genetic approaches, while the field's reliance on WEIRD samples limits the cross-cultural generalizability of its findings. Additionally, vague environmental definitions and a lack of longitudinal epigenetic research hinder efforts to map causal pathways between context and trait change. Future research must adopt integrative frameworks that combine genomic, psychological, environmental, and cultural dimensions to advance the science of personality. For example, this can be achieved by leveraging extensive data and epigenetic tools, refining environmental measurement, and expanding studies to diverse global populations.

Ultimately, synthesizing findings across behavioral genetics, developmental psychology, and molecular biology enriches our theoretical understanding of personality development and paves the way for personalized interventions in education, therapy, and healthcare. By examining the reciprocal interactions of nature and nurture, researchers and practitioners can more effectively support individuals across the lifespan—recognizing both the persistent stability and the transformative potential of personality.

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