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The Ethical and Policy Implications of Epigenetic Research: An Analysis of the TCPS 2

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Article abstract

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ARTICLE (ÉVALUÉ PAR LES PAIRS / PEER-REVIEWED)

The Ethical and Policy Implications of Epigenetic Research: An Analysis of the TCPS 2

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Résumé

L'épigénétique est l'étude des modifications moléculaires potentiellement héréditaires de l'ADN et de la chromatine, susceptibles d'altérer la régulation de l'expression génétique. La recherche épigénétique pourrait potentiellement éclairer de nouvelles approches en matière d'évaluation des risques, de diagnostic et de traitement. **Objectif :** La présente analyse vise à déterminer si l'Énoncé de politique des trois conseils : Éthique de la recherche avec des êtres humains 2 (EPTC 2) offre une protection complète pour la conduite de la recherche épigénétique. Ces conclusions pourraient éclairer les modifications apportées aux politiques et l'élaboration de futures politiques qui tiennent compte de l'épigénétique et des domaines émergents de la technologie génomique. De plus, ces informations profitent aux personnes ou aux groupes menant des recherches épigénétiques. **Contexte :** La recherche épigénétique pose des défis éthiques nuancés et distincts qui diffèrent de ceux rencontrés dans d'autres domaines de la recherche génomique. Le présent document applique le triangle d'analyse des politiques de Walt et Gilson (contexte, contenu, processus et acteurs) pour évaluer dans quelle mesure l'EPTC 2 offre une protection en matière d'éthique de la recherche qui s'étend à l'épigénétique. **Analyse éthique et politique :** L'EPTC 2 offre des orientations détaillées pour la recherche en génétique, qui sont tout à fait applicables et s'étendent de manière appropriée à la recherche spécifique à l'épigénétique. Toutefois, les révisions ultérieures gagneraient à modifier la définition de la « génétique » pour utiliser le terme plus inclusif de « génomique » et à l'étendre explicitement à d'autres approches de recherche génomique, y compris l'épigénétique. En outre, le consentement général devrait mentionner de manière transparente la possibilité que les données soient utilisées pour des recherches impliquant des technologies génomiques différentes de celles de l'étude initiale. **Conclusion :** Le EPTC 2 constitue une base solide pour une recherche épigénétique éthique. Toutefois, des modifications mineures permettraient d'offrir une protection plus complète aux participants et aux chercheurs, garantissant ainsi que la politique reste pertinente et adaptée à ce domaine en rapide évolution.

Mots-clés

exposome, épigénétique, politique, éthique, recherche, génétique

Abstract

Epigenetics is the study of potentially heritable molecular modifications to DNA and chromatin, which can alter the regulation of gene expression. Epigenetic research can potentially inform new risk assessment, diagnosis, and treatment approaches. **Purpose:** This analysis seeks to identify whether Canada's Tri-Council Policy Statement: Ethical Conduct for Research Involving Humans 2 (TCPS 2) provides comprehensive protection for the conduct of epigenetic research. These findings could inform policy amendments and future policy development that is inclusive of epigenetics and emerging areas of genomic technology. Additionally, this information benefits individuals or groups conducting epigenetic research. **Background:** Epigenetic research poses nuanced and distinct ethical challenges that differ from those in other areas of genomic research. This paper applies the Walt and Gilson policy analysis triangle (context, content, process, and actors) to evaluate the adequacy of the TCPS 2 in providing protection for research ethics that extends to epigenetics. **Ethical and Policy Analysis:** The TCPS 2 offers extensive guidance for genetics research, which is strongly applicable and extends appropriately to epigenetic-specific research. However, subsequent revisions would benefit from modifying the definition of 'genetics' to use the more inclusive term 'genomics' and explicitly extending it to other genomic research approaches, including epigenetics. Furthermore, broad consent should be transparent about the possibility that data may be used for research involving genomic technologies different from those in the original study. **Conclusion:** The TCPS 2 provides a strong foundation for ethical epigenetics research. However, minor amendments would provide more comprehensive protection for participants and researchers, ensuring the policy remains relevant and adequate for this rapidly evolving field.

Keywords

exposome, epigenetics, policy, ethics, research, genetics

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INTRODUCTION

Epigenetics is the study of potentially heritable, and possibly reversible, molecular modifications to DNA and chromatin that alter the regulation of gene expression (1,2). Some epigenetic changes are a typical part of the aging process, while others are pathological and may contribute to increased disease risk (3). DNA methylation is the most extensively studied epigenetic mechanism (1). Other epigenetic processes include histone modification, chromatin remodelling, and non-coding RNA (2). However, much remains to be discovered about their individual and collective roles in disease development (2) (see Appendix A for a glossary of terms).

Epigenetics is a complementary approach to genetics research as it examines gene-environment interactions, providing holistic insight into potentially modifiable factors that contribute to health outcomes. However, epigenetics is distinct from genetics in that while genetic inheritance is relatively stable, epigenetics is a dynamic process influenced by the exposome — the cumulative non-genetic environmental exposures that occur over a lifetime that alter our biology, including those from the physical, chemical, social, and built environments within an individual's ecosystem (4-7).

Recently, the subfields of environmental and social epigenetics have begun to expand, bridging the fields of epidemiology and molecular biology (8). Social epigenetics examines the biological pathways through which diverse social experiences, practices, and environments affect health outcomes in individuals (9). These factors arise from the social and structural determinants of health and may include trauma, discrimination, stigmatization, and marginalization (10). Examples include the observation of differential DNA methylation in Holocaust survivors and Indigenous Peoples of Alaska in association with historical trauma (11,12). Environmental epigenetics examines the molecular processes underlying how environmental exposures may contribute to epigenetic changes that can alter gene expression (13). Exposures may include factors associated with climate change or environmental toxins. This topic is especially relevant to discourses on the health impacts of climate change and planetary health. Research demonstrating associations between environmental exposures and modifications to the epigenome have prompted a re-evaluation of gene-centric views, such as genetic essentialism, determinism, and reductionism, which suggest that an individual's phenotype, traits, or behaviours are entirely a result of their genetic composition, or that their biological make-up forms their essence (14) — such views discount how the social and physical environment may shape a person's biology and phenotype.

Currently, epigenetic therapies are used in clinical practice, particularly in the oncology context, with an increasing number of clinical trials underway (15). With further research, epigenetic marks may offer unique insight into the pathological molecular processes that contribute to disease susceptibility, and epigenetic biomarkers may become clinically important for diagnosis and risk assessment (3).

Epigenetic research shares ethical considerations with genetic research, such as concerns for privacy and confidentiality, informed consent, equity, and access. However, identifying environmental, social, and structural determinants of health associated with epigenetic modifications introduces nuanced ethical issues that may result in policy implications for public health and environmental justice (16-20). Therefore, this paper analyzes whether the *Tri-Council Policy Statement: Ethical Conduct for Research Involving Humans 2* (TCPS 2), Canada's principle-based policy for conducting ethical human research, provides protection for scientists and study participants that extends to the ethical issues arising from epigenetic research. These findings may inform the need for future policy amendments related to epigenetics.

POLICY ANALYSIS FRAMEWORK

Policy problem identification involves assessing what is valued or deemed just, identifying gaps, and then evaluating the alternatives that policymakers should pursue (21). Ideally, policy development would be proactive, a preventative measure anticipating potential problems. However, rapid scientific advancements such as those experienced in genomic sciences (including epigenetics) are outpacing the ability to predict the numerous potential vulnerabilities. Policies to guide genetic research involving human participants exist in many countries, although the authors are not aware of any that directly address epigenetics.

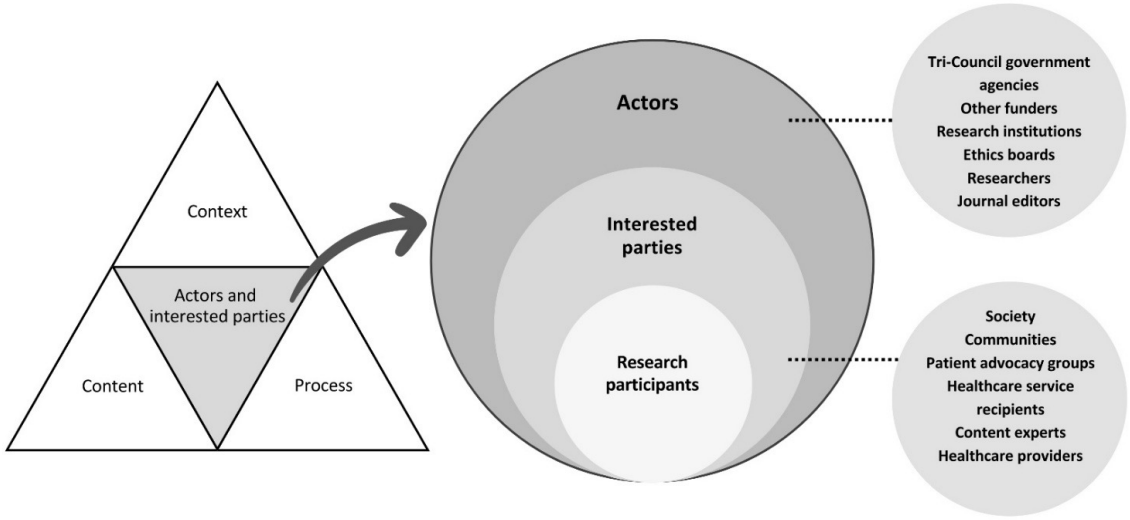
In Canada, the three federal research agencies jointly established the Interagency Advisory Panel on Research Ethics, which is responsible for developing and implementing the TCPS 2 (22). The TCPS 2 includes three core principles to respect human dignity: 1) respect for persons, 2) concern for welfare, and 3) justice. The TCPS framework is highly relevant to discussions on the ethics of epigenetic research, as it considers the impacts on economic and social circumstances, the privacy and security of personal information, the treatment of biological materials, and the risk of stigmatization or discrimination (23). In 2022, revisions were made to the TCPS 2, and several sections pertinent to genetic research were expanded (24).

The TCPS 2 raises the semantic question of whether epigenetics fits neatly under the umbrella term 'genetics' for policy purposes. The TCPS 2, chapter 13, defines human genetic research as "the study of genetic factors responsible for human traits and the interaction of those factors with each other and the environment" (25). It considers genetic research to encompass "the identification of genes that comprise the human genome; functions of genes; the characterization of normal and disease conditions in individuals, biological relatives, families, communities, and groups" (25). It acknowledges that genetic research can have social impacts and has the potential to lead to stigmatization and discrimination. It also states that "…diseases or

personal characteristics are influenced by multiple genes, as well as environmental factors" (25). Furthermore, there is mention of the possibility that genetic research may yield inconclusive results or reveal information about family relationships. Finally, the policy mentions only once the more commonly used and broader term 'genomics' and does not provide a definition. Though epigenetic concepts can be implied from these statements, they are subject to interpretation. Explicit direction would be preferable for consistency.

The Walt and Gilson policy analysis triangle (see Figure 1) considers the contextual or systemic factors influencing policy development, policy content, and the policy-making process (26,27). This framework is typically used retrospectively to analyze public health policy. However, it also provides a suitable framework for analyzing health research policy. Actors are at the centre of the framework as those who actively participate in developing, implementing, and enforcing policies and can include individuals, groups, or organizations (26). Interested parties are those affected by policies (28), and although they can be involved in shaping policy, this is not a requirement for inclusion under this definition. Research participants are the interested parties who are the core recipients of the benefits of policies such as the TCPS 2.

Figure 1. The policy analysis triangle



Created by A Gretchev (2025) in Canva. Actors and interested parties are at the centre of the policy analysis triangle. The actors and interested parties with a vested interest in epigenetic research in Canada are depicted, with research participants as core recipients of the benefits of policies such as the TCPS 2.

Actors involved in policy development, implementation, or enforcement of epigenetic research in Canada include the Tri-Council government agencies, researchers and their institutional research ethics boards, non-government funding sources, and journal editors. These actors all contribute to overseeing participant protection by enforcing adherence to ethical standards that promote equity, diversity, inclusion, and accessibility. From a broad perspective, the social and political context can influence research priorities and funding. Therefore, society is an interested party that can not only influence the policy agenda, but it is also directly affected by policy implementation. Additionally, research outcomes can provide an evidence base for policy decisions that could affect society and communities through their implementation and ongoing evaluation. Calls for community-engaged research or studies that include patient partners in the design process, such as patient advocacy groups, healthcare service recipients, and other content experts, are becoming increasingly common in Canada (29,30). Medical research with potential clinical applications affects healthcare providers, patients, and populations who may benefit from the research outcomes.

This analysis is structured to examine the ethical issues specific to epigenetic research through the lens of the three core principles of the TCPS 2 (the context). It then evaluates the extent to which relevant TCPS 2 provisions address these issues and their adequacy for guiding ethical conduct in epigenetic research (the content). Finally, it outlines recommendations for future revisions to the TCPS 2 to better accommodate emerging ethical challenges in genomic research (the process).

ANALYSIS OF THE TCPS 2

Respect for Persons

Actors

The principle of respect for persons highlights the inherent value of all human beings and ensures that research participants are treated with due consideration (8). Research participants are the primary beneficiaries of this principle. However, researchers must also be vigilant against potential violations of respect, and research ethics boards are responsible for oversight to ensure that studies are designed to maximize this principle. Autonomy encompasses an individual's right to consent through free and informed choice (23).

Context

To consent to participate in research, individuals must receive detailed information about the study, including its risks and benefits. However, in the context of epigenetic research, understanding such information requires health literacy, genetic literacy, and awareness of the complexities of epigenetic mechanisms and their potential to influence health outcomes, which can be challenging to grasp. This can complicate the informed consent process. The challenges related to informed consent necessitate transparent processes that provide information in terms that are easily understood by study participants and allow adequate time for consideration. Broad consent is commonly used in genetics research to permit the use of specimens for future studies and may not adequately convey the additional risks associated with epigenetic research. Broad consent for potential epigenetic research on samples should clearly specify the intended uses, describe how the data and specimens may be used, and outline the possible benefits and risks associated with epigenetic research.

Content

The TCPS 2 covers general consent in Chapter three, and Chapter 12, Section C, extends the consent guidance to include the secondary use of human biological materials for research purposes (23). Additionally, the 2022 revisions to the TCPS 2 include the addition of Chapter 3, section E, on broad consent, defined as “consent for future unspecified research” (31). This is a beneficial addition that is relevant to epigenetics research. Section 3.13 also requires that researchers seek consent for research separately from consent for collecting, using, and storing biological materials. These comprehensive stipulations address the concerns for informed consent described previously. Therefore, provided researchers include the risks and benefits associated with epigenetic research regarding the nature of the data collected and examined, and give ample time for research participants to understand what they are consenting to, the deontological principle of respect for persons in epigenetic research should be achievable.

Concern for Welfare

Actors

Respect for persons and concern for welfare overlap in that conducting research respectfully enhances the well-being of research participants. However, participant welfare also involves distinct considerations beyond respect. Researchers and research ethics boards protect the welfare of research participants and actively promote their well-being when foreseeable risks are identified. Welfare concerns encompass quality of life, including physical, mental, and spiritual well-being, socio-economic circumstances, and physical environments (32). This is particularly salient in epigenetic research, where social determinants such as trauma, discrimination, and stigmatization, along with environmental exposures including toxins, pollution, or tobacco smoke, have been linked to adverse health outcomes potentially mediated by epigenetics (10), as evidence of these associations may inform or support public policy development.

Privacy and confidentiality are crucial concerns for welfare, as maintaining these safeguards protects research participants from harm that could result from unauthorized access to their data. One key distinction of epigenetic research is the possibility that it may reveal sensitive information about lifestyle choices, environmental exposures, or psychological experiences. Research on epigenetic processes, such as DNA methylation, holds promise for developing biomarkers that may facilitate the prediction or early diagnosis of morbidity and mortality. However, identifying behaviours linked to adverse health can have negative consequences. For example, DNA methylation changes have been associated with smoking and alcohol consumption, which raises concerns that lifestyle factors could be inferred from these markers at some point in the future (32,33). An epigenetic smoking status estimator was already developed (34), highlighting the need to consider how these tools might be used in ways that disadvantage individuals, such as marketing these tools to life or health insurance underwriters as risk predictors. However, at this point, the error in these predictors is too large, and they are not advanced enough to apply at the individual level (16).

Context

Protecting participant privacy and confidentiality is paramount to concern for welfare. The unique combination of variants within individual genomes poses an inherent risk of re-identification. A 2018 study demonstrated the capacity to re-identify an individual by name from their genetic data by leveraging publicly available information (35). While the overall risk of re-identification from genetic data remains low, this finding has prompted inquiry into whether epigenetic data presents a comparable or heightened risk. Thomas et al. (36) contend that the identifiability of genetic data is contingent on experimental factors, including the molecular modality, assay type, level of data processing, whether the content is germline or somatic, and the granularity of the structural variant analysis. Consequently, not all genetic data carries an equal risk of re-identification. Based on their scoping review, the authors provided practical guidance for researchers to conduct risk assessments and implement safeguards when using genetic data. There is no definitive evidence to exclude the risk of re-identification from epigenetic data. However, the dynamic and reversible nature of epigenetic modifications reduces the risk when compared to static information derived from DNA sequencing (16,37).

The return of results from epigenetic research necessitates a careful consideration of potential harms in balance with the benefits. However, policies for general genetic testing apply in that results should be clinically valid, significant, and actionable (38,39). Dyke et al. provide additional considerations specific to returning epigenetic results (40). The authors caution that

determining the validity and actionability of epigenetic results is especially challenging due to the accuracy of technology, the dynamic stability of epigenetic changes, the lack of definitive evidence for causation, tissue variability, and clinical validity (20,40).

Several established models for informed consent exist regarding the return of genetic results to research participants (41,42). However, inconsistent approaches are observed globally, partly due to the heterogeneous legislative landscape, which influences the return of results (43). In Canada, there is currently no legal mandate compelling the return of genetic results to research participants (43). Nevertheless, the prevailing practice standard within the Canadian research community is to provide results that are deemed clinically actionable (43). The US National Academies of Sciences, Engineering, and Medicine (NASEM) provided comprehensive guidance on return of results in their 2018 consensus report (42). The report strongly recommends that informed consent documents specify offered results, justify the selection of particular results, discuss the risks and benefits associated with receiving results, and provide a mechanism to opt out (42). These recommendations establish a framework for transparent and responsible communication between researchers and participants, which is suitable for extension to epigenetic studies, with additional consideration given to the risk of mistakenly attributing causality to associations between environmental factors and epigenetic variation.

Since epigenetic research reveals associations, participants must be well-informed about the limitations of epigenetic data to make causal inferences and avoid misinterpretation. While further research is needed to substantiate these findings beyond mere associations, it is prudent to anticipate the possibility that this information may expose individuals to stigmatization or discrimination (20). This is significant as evidence suggests that fear of discrimination based on genetic information causes individuals to avoid participating in research (44,45). Moreover, when researchers communicate their findings, they must explicitly acknowledge the structural determinants (e.g., structural racism, socioeconomic inequality, colonialism, and discriminatory public policies) that pose individual and population-level risk factors for adverse health outcomes (46,47). To translate research results into interventions that affect populations, research must move from being descriptive to focusing on concrete strategies to influence change. In epigenetic research, this includes acknowledging the limitations in establishing causality with exploratory research and, as knowledge and technologies advance, conducting experimental research to test potential epigenetic interventions (48).

Content

The addition of Article 3.13 in the TCPS 2 imparts a shared responsibility among the researcher, repository authorities, and future researchers to ensure that participant privacy and confidentiality are upheld through proper consent processes. Though epigenetics, genetics, and genomics are not explicitly mentioned, section 3.13(h) requires that broad consent include “whether the research will (if known) or might include whole genome sequencing or similar technologies that may pose a substantial risk of re-identification of the participant or identification of material incidental findings (when appropriate)” (31). There are currently no guidelines on the return of results to research participants in epigenetic studies, as the clinical significance and application of epigenetic data are not sufficiently established. Hence, in the absence of a suitable policy, researchers should carefully consider whether doing so provides any benefit to study participants and follow current best-practice recommendations. Additionally, Article 3.4 on the disclosure of incidental findings applies to the return of results and is discussed in the context of foreseeable findings. This section references Article 13.2 and directs genetic researchers to develop a plan for managing findings and submitting the plan to their research ethics board for review. Article 13.2 mentions potential implications for employment or insurance, or the revelation of information that has implications for family members. Therefore, provided researchers follow the guidance of the TCPS 2 in addressing privacy risks and the plan for return of results, the policy should sufficiently extend to epigenetic research. It is also advisable to highlight the limitations in interpreting epigenetic data.

Justice

Actors

The principle of distributive justice in research ethics addresses the equal distribution of burdens and benefits (23,49). It is essential to distinguish between equitable and equal treatment, as overlooking factors contributing to disparities can perpetuate inequities (23). Social factors have been linked to epigenetic modifications, including alterations in DNA methylation, which are associated with experiences of discrimination, racism, and marginalization (50,51). However, the clinical implications of these epigenetic modifications are still unclear. Researchers must be mindful of historical injustices, such as the legacy of colonization, which have contributed to social and environmental determinants of poor health. Failure to acknowledge these injustices may perpetuate stereotypes and compound harm through re-traumatization (20). Research institutions, funders, and ethics boards can contribute by supporting community-engaged, culturally safe research designed to generate tangible benefits for the populations involved. Conversely, studying the physiological changes resulting from adverse social experiences such as trauma and neglect can offer valuable insights, potentially strengthening efforts to disrupt intergenerational cycles of risk or inform more protective public policy. Researchers working with populations that have experienced systemic disadvantage or that have been historically excluded must be aware of the inherent power imbalances between themselves and study participants and take measures to mitigate potential harm (23).

If epigenetic research advances and provides strong evidence that certain environmental or social factors are a driving force behind epigenetic changes, there is a risk that responsibility for addressing these issues may be placed on individuals rather than society. This raises a significant ethical concern about how accountability for health outcomes is justly distributed (52). Researchers must be cautious in reporting study results to avoid unwarranted targeting of individuals and neglecting to consider the social, political, legal, and environmental structures that create the conditions within which environmental and social exposures occur (52). Many factors are beyond an individual's control to change, and those disproportionately affected by adverse environments bear the most significant exposure burden. Recognizing that these issues are too substantial to be solved at the individual level may help alleviate some of the associated stigma. Conversely, focusing solely on systemic factors may diminish individual agency for meaningful change, which demands an appropriate balance for effective advocacy.

Context

Justice and concern for welfare overlap in efforts to mitigate the potential for stigmatization and discrimination associated with epigenetic findings. Applying an equity, diversity, and inclusivity (EDI) lens to all stages of research, including ethical codes of conduct, is particularly important for research involving populations disproportionately affected by health disparities. This approach supports participant welfare and ensures just treatment. EDI strategies are key considerations for researchers, ethics boards, funders, institutions, journal reviewers, and editors who can enforce alignment with best practices in research design and reporting. How research results are interpreted and framed can further protect participants from stigma and discrimination. While these practices are crucial, they are insufficient to fully safeguard participants, as researchers and ethics boards cannot control how published data will be externally interpreted and used. Genetics research findings have previously been misinterpreted or weaponized to support discriminatory agendas (53-56). Thus, even when research is conducted and reported in ethically rigorous ways from an EDI perspective, there is still a risk of unintended societal harm.

Content

The TCPS 2 provides relevant guidance for researchers to address concerns about justice in epigenetic research. In addition to the policy features described under concern for welfare, Chapter four addresses fairness and equity in research participation (23). This policy section outlines considerations for the appropriate inclusion and exclusion of individuals, the ethical treatment of those whose circumstances render them vulnerable, and the equitable distribution of research burdens and benefits. The consequences of not adhering to these policy practices are substantial, such as being denied funding, ethics approval, or publication. The research community has worked to reconcile historical harms, and upholding the principle of justice has become a priority and is widely embedded in Canadian research practices and policies. Therefore, the TCPS 2, in combination with other EDI resources for researchers, provide extensive guidance to uphold the principle of justice.

PROCESS — RECOMMENDATIONS FOR ACTION

The TCPS 2 establishes the principles for the ethical design, conduct, and review of research involving humans. The 2022 revisions to expand upon genetic research address several ethical concerns relevant to epigenetic research, though some gaps remain. There are many potential vulnerabilities for individuals participating in epigenetic research. The TCPS 2 upholds the principles of respect for persons in epigenetic research through its comprehensive guidance on consent processes, including broad consent, which is often employed in epigenetic research. The policy adequately protects participant welfare through guidance related to the re-identification of epigenetic data and the return of results. It also provides a laudable direction to uphold the principle of justice related to the structural and social concerns arising from epigenetic research.

The process corner of the analysis triangle pertains to policy development. Future revisions to the TCPS 2 should consider modifying the definition of genetics to use the more inclusive term 'genomics', optionally noting that the use of genomics encompasses the rapidly emerging large-scale molecular -omics profiling approaches of epigenomics, transcriptomics, proteomics, metabolomics, and lipidomics. This will ensure that the consideration of these distinct research domains is explicit. Furthermore, information provided for broad consent could include mention that data may be used for research involving genomic technologies different from those used in the original study. These additions can enhance existing policy guidance to ensure comprehensive consent processes that detail the risks associated with epigenetic research, providing greater clarity and transparency for study participants.

CONCLUSION

Navigating the ethical tensions inherent in genomic research requires careful consideration of its impacts on all actors and interested parties while preserving respect, ensuring participant welfare, and promoting justice. In Canada, the TCPS 2, which governs research oversight, provides comprehensive guidance on ethical practices in genomic research. Furthermore, the 2022 revisions address some of the scenarios raised by epigenetic research that may create ethical dilemmas overlooked by previous versions of the framework. However, since it focuses exclusively on genetics and does not explicitly address genomics, epigenetics, or other -omics approaches, vulnerabilities for epigenetic researchers and research participants must be addressed with future revisions. This paper provided recommendations for consideration in future versions of the TCPS 2, including a broader and more inclusive definition of genetics and additional considerations for broad consent. These additions will ensure that policy for ethical conduct in research involving humans is forward-looking, upholds all moral principles equally, and is inclusive of current and emerging genomic research approaches.

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APPENDIX A: GLOSSARY

Ableism	The erroneous practice of discrimination or prejudice against anyone with a perceived disability that does not meet the socially defined norm of being able-bodied (57). This is based on a belief in the superiority of non-disabled people and includes harmful stereotypes and misconceptions about people with disabilities (57).
De novo variant (mutation)	A *de novo* variant is a genetic alteration in a gene's DNA sequence or epigenome that arises for the first time in an individual and is not inherited from their parents (58).
Epigenetics	The study of potentially heritable molecular modifications to DNA and chromatin that regulate gene expression (1). Mechanisms that induce epigenetic modifications include DNA methylation, histone modification, and non-coding RNA (2).
Environmental epigenetics	The molecular processes that underlie how environmental factors may impact biology by contributing to epigenetic changes that alter gene expression (13).
Exposome	The cumulative nongenetic environmental exposures that occur over a lifetime and alter one's biology, including those from the physical, chemical, social, and built environments within an individual's ecosystem (4-7).
Genetics	The study of genes and their effect on inherited traits or conditions (59).
Genetic determinism	Genetic determinism is the belief that a particular genotype invariably leads to a fixed and predefined phenotype, often suggesting that one's genetic makeup dictates one's biological destiny. This perspective overlooks the dynamic interactions between genes and the environment, failing to consider the variability in gene expression. Additionally, determinism does not inherently account for the complexities of heritability, which can be influenced by factors such as penetrance and phenotypic expression (16).
Genetic essentialism	The belief that DNA is the essence of being that defines a person based on their biology, without consideration of social and environmental constructs (16).
Genetic reductionism	The belief that the genetic constitution of an individual is sufficient to explain traits and behaviours (16).
Genomics	The study of the entirety of genes (the genome) and the interactions between those genes and the environment, such as epigenetics (59).
Interested parties	Any party affected by a policy or involved in the policy process.
Penetrance	The percentage of individuals with a specific genotype associated with a trait who exhibit any indications or symptoms of that trait. This percentage may vary depending on age (60).
Phenotype	Genetic makeup and environmental factors influence an individual's physical and functional traits (i.e., phenotype). This encompasses observable characteristics indicating a specific condition or trait, such as hair, eye, and skin coloration (60).
Phenotypic expression	The extent to which a genetic variant manifests in observable traits, including the spectrum of phenotypes that can arise from the variant (60).
Social epigenetics	Social epigenetics examines the biological pathways through which diverse social experiences, practices, and environments affect health outcomes in individuals (9).