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Postmodern evolutionary framework for chronic diseases – cultural evolution allows multicausal explanations

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Non-communicable diseases—such as cardiovascular diseases, cancer, respiratory diseases, diabetes, and chronic pain—pose significant global health challenges, causing millions of deaths annually. Traditionally, holistic frameworks have been developed to analyse these conditions. Although integrating biological, psychological, and social factors, the biopsychosocial model suffers from a lack of detail and practical application. By incorporating cultural evolutionary perspectives, we can better understand how evolutionary influences affect disease susceptibility and persistence. We propose a postmodern, evolutionary-informed biopsychosocial framework that draws on insights from cultural evolution and niche construction theory. This approach spans multiple evolutionary time scales—from immediate behavioural adaptations to long-term genetic and cultural changes—and provides a nuanced view of health condition dynamics. Ultimately, this interdisciplinary framework advances strategies for prevention and treatment by offering a differentiated and effective approach to managing modern health challenges.

Lay summary: A new framework combines biological, psychological, and social factors with cultural evolution to better understand long-term conditions like heart disease, cancer, and diabetes. It spans immediate behavioural changes to long-term genetic and cultural influences, offering improved strategies for prevention and treatment.

KEYWORDS

adaptation and maladaptation, biopsychosocial model, cultural evolution, evolutionary medicine, niche construction theory, non-communicable diseases, social learning

Understanding chronic diseases by integrating biopsychosocial and evolutionary perspectives

According to the latest World Health Organization (WHO) estimates, non-communicable diseases (NCD), commonly known as chronic diseases, responsible in 2016 for 41 million deaths—71% of the 57 million global deaths (World Health Organization, 2018). Cardiovascular diseases accounted for 17.9 million deaths (44% of NCD deaths; 31% of all deaths), cancers for 9.0 million (22%; 16%), chronic respiratory diseases for 3.8 million (9%; 7%), and diabetes for 1.6 million (4%; 3%). NCDs also drive premature mortality: 75% of deaths among adults aged 30–69 years were due to NCDs, and the global probability of dying from one of the four main NCDs at ages 30–69 fell from 22% in 2000 to 18% in 2016 (22% for males, 15% for females). Early detection and treatment are the central focus of many national and international health action plans for NCDs (Global action plan for the prevention and control of noncommunicable diseases, 2013-2020, 2013). NCDs are multifaceted, where biological factors such as bodily dysfunctions or genetic and non-genetic predisposition intersect with psychological factors, including individual behaviours, emotions, and coping mechanisms, as well as social factors that encompass socioeconomic status, community support, healthcare systems, and cultural beliefs. The substantial worldwide impact of NCDs, specifically how they affect both mortality rates and the quality of life for patients, highlights the necessity for more holistic approaches to comprehend and handle these conditions.

In response to this need, the biopsychosocial framework, introduced by George Engel in 1977 (Engel, 1977), offers a more holistic perspective by integrating biological, psychological, and social domains, contrasting the traditional biomedical models which focuses solely on biological domains. Engel argued that health must be understood through the complex interplay of biological variables, psychological factors including mental health and personality, and social elements such as social networks and family support. While ground-breaking, the biopsychosocial framework has been criticised for its lack of specificity and difficulty in practical application (Kaiser et al., 2021; McLaren, 1998; Bolton and Gillett, 2019; Frazier, 2020). This framework does not fully account for why certain vulnerabilities to NCDs exist or persist on different time scales or in (sub-) populations.

Post-modern evolutionary concepts can fill this gap by explaining why certain diseases persist in (sub-) populations, how our evolutionary past may predispose us to NCDs, and the reasons behind varied susceptibilities to diseases among individuals (Nesse and Stearns, 2008). These concepts explain the dynamics of societal and behavioural transformations through processes of learning, imitation, and transmission. Integrating evolutionary principles into the biopsychosocial framework may enrich our understanding of NCDs aetiology and progression (Hunt et al., 2023). Evolutionary medicine provides insights into why certain maladaptive responses may have been helpful in ancient environments but are detrimental in modern contexts, leading to NCDs (Nesse and Stearns, 2008; Nesse and Schulkin, 2019; Plomp et al., 2022). By acknowledging the importance of spatial and temporal scales of NCDs, healthcare systems can customise interventions more efficiently. It can guide public health efforts to focus on prevention strategies that align with our evolved biology while also adapting to current environmental challenges. However, the Extended Evolutionary Synthesis is a valuable postmodern approach that extends our knowledge of evolution, especially for the role of human culture and its impact on health and disease, and has so far not yet been used in explaining NCDs (Lange, 2023).

Extended evolutionary synthesis

Humans are subject to natural selection, but simultaneously, they can transcend their evolutionary trajectory. This fact that the human being is a bearer of culture was slow to be incorporated within the evolutionary theory (Smocovitis, 2012). Culture and free will are incompatible with the classical theory of evolution (Modern Synthesis) because its deterministic, gene-centric explanation of the principles of life contradicted our nature as "purposive living systems" (Laland et al., 2019). The degree of freedom in which intended cultural evolution is possible for humans cannot be causally justified genetically, even if genetic foundations exist. Nor can it be explained how humans control and regulate their environments (Smocovitis, 2012). The Modern Synthesis assumes genetic variation and its inheritance as the only basis of inheritance and evolution. In the recent past, genetic inheritance was identified as a serious limitation leading to the Extended Evolutionary Synthesis (Laland et al., 2015; Lange, 2023). As a central novel perspective, Extended Evolutionary Synthesis describes inclusive inheritance and cultural evolution, where inclusive inheritance includes genetic and other forms of inheritance that have evolutionary significance (Jablonka and Lamb, 2020).

Unlike biological evolution, which is driven by genetic mutation and natural selection, cultural evolution is based on the transmission of information that is not encoded in genes. Cultural evolution relies on mechanisms such as learning, imitation, and social interaction (Richerson and Boyd, 2006; McCaffree, 2022). Behaviour, language, traditions and symbols can be passed on. Cultural inheritance can occur horizontally within the same generation or vertically from one generation to the next. In both cases, the transfer of information can take place through the media, education, and between different social groups. In cultural evolution, the core principle of natural selection as the dominant mechanism of selection in biological evolution, which leads to the survival of the fittest, is not necessarily present. Nevertheless, there is evolutionary change (Dennett, 1995; Laland et al., 2000; Laland et al., 2001; Richerson and Boyd, 2006; Mesoudi, 2011; Dennett, 2017; Rosenberg, 2022). Selection in cultural evolution is based on criteria set by humans themselves, and evolutionary changes occur much faster than by genetic means (Lieberman, 2014). Culture has not stopped genetic evolution, but has overwritten it. Today, human evolvability is dominated by cultural evolution (Lala et al., 2024). Not all new ideas or practices are adopted; they must appear beneficial or at least acceptable to the community for certain goals to survive. These

goals might include short-term social objectives, economic interests, norms and ideologies, technological innovation, life prolongation, or the treatment of diseases. Many of them are not intended to increase biological fitness. Cultural evolution is also characterised by its cumulative nature, enabling the construction of new cultural achievements on pre-existing knowledge. This can lead to the emergence of ever more complex technologies, social structures and ideas, with humans being the only creatures to practise cumulative culture on a large scale. The idea of purposeful, conscious cultural evolution is fully compatible with postmodern evolutionary theory. The Extended Evolutionary Synthesis opens up the possibility of recognising the relevance of evolution on NCDs.

Maladaptive consequences of cultural evolution

There is adaptive cultural evolution in the Darwinian sense (e.g. the early manufacture of tools, social learning), including medical progress. On the other hand, there is evolutionary maladaptation (mismatches), which must be seen in the inability of humans to cope adequately with complex, global, and long-term challenges. We must at least speak of adaptation delays, which are evident in decades of sluggish attempts to adaptively correct the consequences of socio-technical behaviour (Rosenberg, 2022; Odling-Smee, 2024). While not always adaptive in the Darwinian sense, human behaviour often exhibits purposefulness, guided by alternative principles. In addition, the increasingly rapid dynamics in our socio-techno-cultural epoch (or Anthropocene) make adaptation almost impossible, given the speed and complexity of changes (Blaisdell, 2018). Population-wide natural adaptation occurs over thousands up to millions of years, in contrast to the rapid uptake of new cultural behaviours, especially technical innovations. In all cases, human culture in today's socio-technical world often does not have much in common with adaptation in the biological evolutionary sense; often, the opposite is the consequence in the form of unavoidable maladaptations (mismatches) (Lieberman, 2014; Hayes et al., 2020). Interspecies cultural evolutionary processes are present via our modern lifestyle, techniques and behaviour (Lieberman, 2014; Lange, 2021; McCaffree, 2022; Lange, 2023). Cultural maladaptation occurs when a cultural practice, belief, or innovation that was once beneficial or intended to improve living standards, social cohesion, or technological efficiency instead produces unintended negative consequences, reduces well-being, or becomes mismatched with the ecological, social, or technological context in which it operates. By incorporating evolutionary adaptation and maladaptation, we can explore and analyse NCDs in a more comprehensive manner.

Evolution meets biopsychosocial framework

Recently, the interspecies evolutionary processes were integrated into one framework by extending the BPS with Tinbergen's 4 questions (Tinbergen, 1963; Nesse, 2013; Hunt et al., 2023). All four questions and explanations are important for acquiring a comprehensive understanding of biological and behavioural characteristics. This is especially true when they are applied together in context (Hayes et al., 2020). Using the example of chronic back pain, we illustrate in very general terms the understanding of Tinbergen's questions. The first two causal questions to explain a behaviour or a biological trait can be paraphrased as:

1. "How does the trait or behaviour develop over the individual's lifetime?" (development). Chronic back pain may start with an acute injury or repeated strain, leading to sensitisation of pain pathways. Psychological factors (e.g., stress, anxiety) and lifestyle habits (e.g., poor posture, lack of exercise) can contribute to its persistence.
2. "How does the trait or behaviour work on a physical basis within an organism or with an individual?" (mechanism). Chronic back pain can be caused by factors like nerve damage, inflammation, muscle dysfunction, or spinal issues (e.g., herniated discs, arthritis). Neurobiological mechanisms include changes in pain processing in the brain and spinal cord.

The how questions are typical questions that medical research addresses. Other causes refer to the evolutionary function, purpose, or benefit of a biological trait or behaviour, using questions such as:

3. "Why does the trait or behaviour enhance survival and reproduction?" (function). Chronic back pain itself is not adaptive, but acute pain serves as a protective mechanism to prevent further injury. However, chronic back pain may result from a maladaptive over-activation of pain pathways.
4. "Why did this trait or behaviour arise over the course of evolution and why did it spread compared to alternative traits" (phylogeny, evolutionary history): Human bipedalism has placed significant stress on the spine, making back pain a common issue. Evolutionarily, our spine may not have fully adapted to prolonged sitting or modern lifestyles, contributing to the high prevalence of chronic back pain.

With the last question, the evolutionary history of a feature in its sequential changes is of more interest than its adaptive advantage. The why questions are typical questions asked by evolutionary researchers, including in evolutionary medicine (Nesse and Stearns, 2008). Next, we will explore the transferability of the how-and-why questions from their original context of physiological and behavioural traits to cultural evolution and the psychological and social domains, where they can be equally beneficial.

We create a novel theoretical framework that enhances the foundational domains of the BPS by incorporating insights from the Extended Evolutionary Synthesis, focussing specifically on theories concerning cultural evolution. This could benefit a broad array of

stakeholders, including researchers, clinicians, ethicists, sociologists, economists, policymakers, and public health officials, by facilitating the development of robust hypotheses and theories, the systematic examination of the underlying causes of NCDs across spatial and temporal scales, and improvements in multiple outcomes. Our framework is suitable for NCDs that have spread significantly over the past generations to the present day and therefore are accessible for a (cultural-) evolutionary view.

Niche construction theory and cultural evolutions

In the context of the Extended Evolutionary Synthesis, niche construction theory is considered a fundamental aspect that will be briefly introduced here. This theory recognises that organisms construct their biotic and abiotic environment actively, systematically, and directionally (Odling-Smee et al., 2013). Among the ecosystem, beavers build intricate dams, birds build nests, and corals create even larger-scale constructions. In the environment of such structures, not only does the evolution of the species that build these structures change (niche constructor) and a recipient species (maybe the same species as niche constructor), but often also the evolution of numerous other species that live in these niches also changes. Thus, it is easy to see that the *construction of coral reefs* attracts countless species whose own evolution would not be possible without that of the corals.

Niche construction fundamentally changes the selection conditions. The new selection environment is systematically and purposefully created by organisms (e.g., through building bird nests, spider webs, termite mounds, or developing human culture), while previous selection conditions may remain. Adaptation arises from this new view as a consequence of natural selection and the niche construction. Evolution thus does not progress exclusively by way of natural selection; the restriction of the Modern Synthesis on natural selection ignores "the role of organisms as imposing a bias on selection through systematically shaping the properties of selective environments" (Laland et al., 2019). Both niche construction and the ecological environment are inherited for numerous generations, interact with each other and co-evolve in the complex interplay of many feedback loops (Odling-Smee, 2024). In the sense of an organism-environment coevolution, niche construction is a postmodern theory.

The role of genes also changes in the niche construction theory. In the traditional theory of evolution, genetic variation is seen as the primary cause of evolutionary change. This view is considered reductionist today. A simple analogy may illustrate this: claiming that the lights in my living room are "caused" by a power plant that generates electricity. While the electricity from the plant is necessary, it is not by itself the reason why my lights are on—I also have to decide to flip the switch, and many other factors are involved. In the same way, genes are necessary influences, but they are not sufficient causes of the existence and behaviour of organisms. Niche construction, together with non-genetic (cultural) inheritance and directed (behavioural) variation, therefore represents a novel non-selective pathway of adaptation (Pocheville, 2019).

The showcase example of a niche construction in humans: lactose tolerance

In recent years, niche construction theory has been applied in extensive knowledge to humans, especially to the environment of the aforementioned cultural inheritance (Laland et al., 2001; Kendal et al., 2011; Laland and O'Brien, 2011). Humans today are constructing countless different niches in which their evolution is occurring, and in which they influence or weaken natural selection or eliminate it over longer periods of time. This includes the internet, genetic engineering, nano-medicine, and metropolises of unprecedented size, to name just a few. A showcase example of an evolutionary niche is the gene-culture co-evolution of dairy farming. Humans are highly lactose-tolerant in the northern hemisphere; one-third of human's digest and tolerate lactose even in adulthood (Figure 1). By contrast, in other mammals, uncoupling from the mother's breast is beneficial and necessary and is accompanied by increasing lactose intolerance and self-feeding off the young, while the mother becomes free for new offspring. With humans, that evolutionary path was changed. After humans settled down a few thousand years ago, some individuals became lactose tolerant due to a mutation in a regulatory region of the β-galactosidase enzyme (lactase-phlorizin hydrolase: LPH) that occurred independently in different places (Anguita-Ruiz et al., 2020). Adults probably recognised that the supply of animal milk provided valuable nutrition for their children. However, the mutation alone, although fitness-enhancing, was not sufficient to bring about the lactase persistence phenotype (lactose tolerance) that is now widespread across the globe. Rather, man-made niche construction emerged with extensive dairy farming (domesticated livestock). Only dairy farming, and thus cultural inheritance and evolution, ensured that the lactase persistence phenotype could spread in the population (Cavalli-Sforza and Feldman, 1981; Gerbault et al., 2011). Dairy farming and niche construction in general is thus both an evolutionary cause and consequence. By analogy, one might argue that today's widespread obesity also reflects a form of human-driven niche construction, where modern food environments and lifestyles have reshaped selective pressures at the population level (Figure 1).

Humans and countless animal species are not passive recipients of natural selection pressures, but construct and manage their own functional niches. In this way, "life contributes to its own evolution" (Odling-Smee, 2024).

Cognitive gadgets as another form of gene-culture coevolution

We add another form of gene-culture coevolution and niche construction. The theory of "cognitive gadgets" (Heyes, 2018) offers

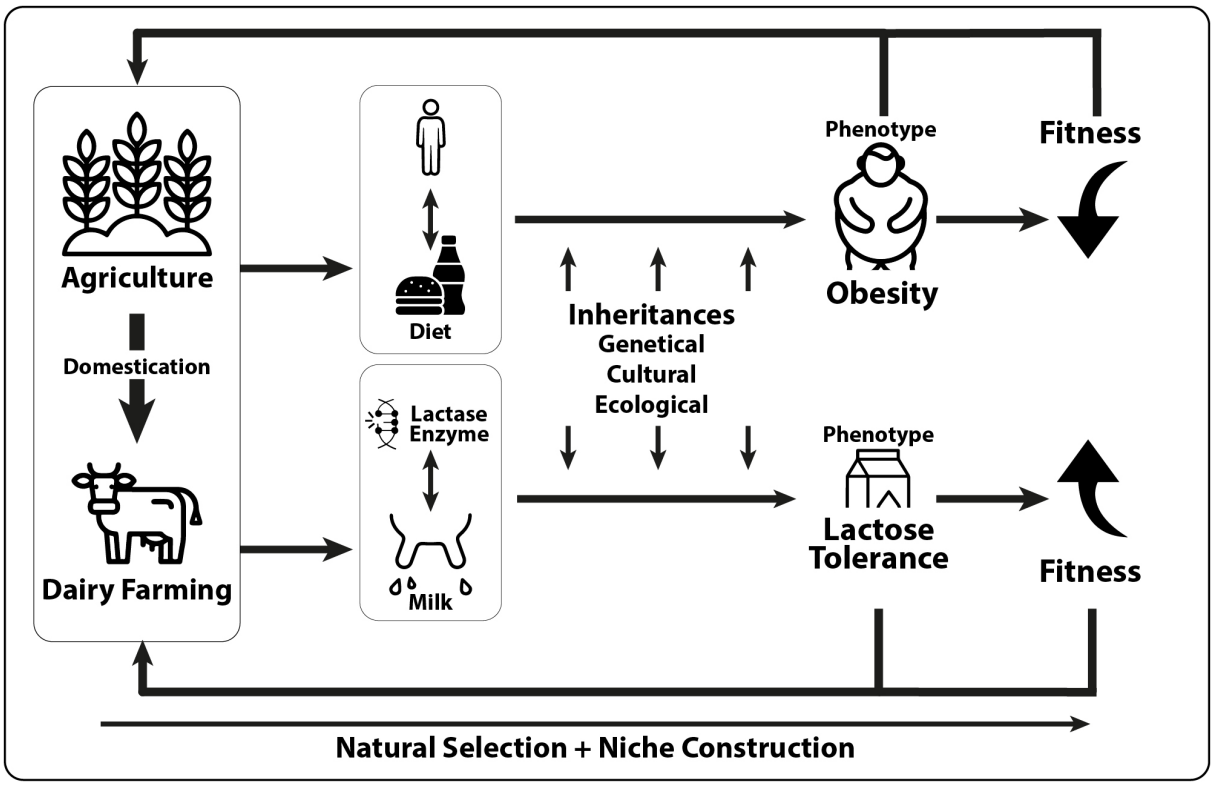

FIGURE 1
Human NC. Niche construction, here the example of lactose tolerance and obesity, proceeds in iterative recursive causal explanatory steps (arrows) and leads to increased fitness (adaptation) or decreased fitness (maladaptation). Feedback loops, as shown here, are an important element in the framework we are developing in this paper. Genetic, cultural and ecological inheritance contributes to gene-culture co-evolution.

an alternative view of the evolution of human cognition. It is argued that many cognitive abilities that have traditionally been considered innate and genetically determined are actually culturally transmitted and learned. We refer to these abilities, such as our language or reading, as "cognitive gadgets", learned inventions or transformations of phylogenetically old cognitive mechanisms. For example, learning a language in childhood is associated with structural changes in the brain during development (May, 2011; Zatorre et al., 2012). Similarly, learning to read leads to changes in the brain regions associated with visual processing (Chyl et al., 2021). However, these skills develop through social learning and cultural transmission rather than solely through genetic evolution. Social learning is learning by imitating or copying each other. According to Heyes' approach, cultural transmission and refinement of cognitive skills occur in a manner similar to the transmission of tools and genetic traits in a population. Culture and social learning are crucial factors that shape human cognition alongside genetic evolution. The newly acquired abilities extend beyond the potential of genes alone.

Unlike lactose tolerance, the cognitive gadgets do not result in changes in gene frequency in humans. Rather, existing genetic tendencies in humans are transformed into new abilities through social learning and structural brain changes within a single individual lifetime, which is seen as developmental niche construction (see: Different spatio-temporal scales of niche construction). Despite the temporally different dimensions, gene-culture coevolution is present in both cases, with lactose tolerance and in the case of cognitive gadgets.

Concerning niche construction, the environment we create through language, reading and social learning influences not only the current generation but also - including the effects of the internet - future generations, as cultural practices and knowledge are passed on, i.e. inherited. These are typical components of a niche construction theory with phylogenetic dynamics, including feedback loops (Lange, 2023).

Different spatio-temporal scales of niche construction

Within a niche, different spatial (e.g. population versus individual) and temporal (e.g. millions of years versus some generations) processes can take place. In earlier work, the taxonomy was described, which contains a definition of the spatio-temporal scales within the NCT (Coninx and Stephan, 2021; Fabry, 2021; Coninx, 2023). Based on this definition, a distinction can be made between 4 scales of NC:

A. phylogenetic, concerning evolutionary changes within a population over several to hundreds or more generations.

B. sociogenetic, relating to social and cultural evolution, typically of a society or subpopulation within one and along several generations.

C. ontogenetic, dealing with an individual's development.

D. microgenetic, focussing on immediate and situational modifications of an individual.

Each of them offers a unique lens through which to examine the dynamic interactions between living beings and their surroundings (see Tables 1A–D).

Phylogenetic niche construction explains how environmental changes driven by a population's niche contribution can shape its genetic makeup in the long-term, key aspect of adaptation in a gene-culture co-evolution manner. Adaptation and maladaptation are assessed by biological fitness in the number of offspring who survive to reproduce at the phylogenetic level (normative criterion of (mal-)adaptation). However, in the study of phylogenetic niche construction and cultural evolution, sociogenetic, ontogenetic and microgenetic niche construction in humans, the focus shifts beyond biological survival and genetic transmission. In cultural evolution, adaptations can also bring social, technological, or cultural advantages. Other normative criteria are therefore needed for (mal-)adaptation within the cultural-evolutionary spatio-temporal framework. They evaluate the efficiency of the fulfilment of individual, social, or technological tasks. The next three spatio-temporal scales describe natural adaptation and maladaptation in populations over generations (sociogenetic), within lifespans (ontogenetic), and in immediate behaviours (microgenetic).

Sociogenetic niche construction involves a (sub) population shaping its environment through cultural behaviour. These faster, non-genetically heritable changes bypass slower genetic adaptations. Collective changes can be passed within a generation (horizontal inheritance) or across generations (vertical inheritance), including both tangible assets and intangible ones, like knowledge and norms. Sociogenetics utilises different criteria to assess adaptation and maladaptation, unlike the fitness criterion in phylogenetics (Coninx, 2023). The United Nations' Transforming the World: 2030 Agenda for Sustainable Development is an appropriate action plan for addressing the needs of people, the planet, and prosperity. It displays 17 goals and 169 targets to end poverty, protect the environment, promote peace and ensure human rights by 2030 (https://sdgs.un.org/2030agenda). On a lower level, the philosopher Hans Jonas put it this way: "Act so that the effects of your action are compatible with the permanence of genuine human life" (Jonas, 1985).

TABLE 1 A conceptual framework for integrating the biopsychosocial domains with the spatio-temporal scales of niche construction in the study of NCDs.

	Domains of the biopsychosocial framework			
Spatio-temporal scales of NC	Biological[1]	Psychological[2]	Social[3]	
Phylogenetic[A] Spatial Scope: Species, Populations Temporal Scope: Multiple/Many generations Inheritance: Cultural, Cultural-genetic Criterion: Fitness/Offsprings, UN-Agenda 2030	Exploring the biological *how* and *why* questions at the phylogenetic scale. A1	Exploring the psychological *how* and *why* questions at the phylogenetic scale. A2	Exploring the social *how* and *why* questions at the phylogenetic scale. A3	Different spatio-temporal scale 3. Inter-scales model
Sociogenetic[B] Spatial Scope: (Sub-) Populations Temporal Scope: Multiple generations Inheritance: Non-genetic Criterion: UN-Agenda 2030	Exploring the biological *how* and *why* questions at the sociogenetic scale. B1	Exploring the psychological *how* and *why* questions at the sociogenetic scale. B2	Exploring the social *how* and *why* questions at the sociogenetic scale. B3	
Ontogenetic[C] Spatial Scope: Individual Temporal Scope: Development stages Inheritance: Intra-individual Criterion: Personal well being	Exploring the biological *how* and *why* questions at the ontogenetic scale. C1	Exploring the psychological *how* and *why* questions at the ontogenetic scale. C2	Exploring the social *how* and *why* questions at the ontogenetic scale. C3	
Microgenetic[D] Spatial Scope: Individual Temporal Scope: Here and now Inheritance: Situation-bound Criterion: Capacity to tackle a local change	Exploring the biological *how* and *why* questions at the microgenetic scale. D1	Exploring the psychological *how* and *why* questions at the microgenetic scale. D2	Exploring the social *how* and *why* questions at the microgenetic scale. D3	
	Same spatio-temporal scale 1. Same scale model 2. Same scale, different stakeholder model			

This multi-domain and spatio-temporal framework integrates the biopsychosocial domains with insights from cultural - evolutionary theories, particularly within the context of the Extended Evolutionary Synthesis, including niche construction for exploring NCDs. The framework applies three models: (1) Same-scale model: Niche modifications within a single spatio-temporal scale impact the same stakeholders positively, neutrally, or negatively, (2) Same scale different stakeholder model: Niche changes at the same spatio-temporal scale affect different stakeholders differently based on their interests, and (3) Inter-scales model: Niche changes across spatio-temporal scales create reinforcing cycles of positive and negative effects, impacting both same and different stakeholders.

Ontogenetic niche construction describes how individuals interact with and change their environment, shaping their characteristics throughout lives. It highlights personal differences in forming stable patterns through different life stages. In medical cases, intra-individual transmission is key to how traits are developed and culturally maintained. Personal modifications, such as customizing living spaces or relationships, influence skill development, emotional regulation, and self-identity, impacting well-being. Such changes are often sustained over time, serving as consistent influences on personal development. Personal well-being associated with a decent, meaningful, dignified life is the associated normative criterion of (mal-)adaptation in ontogenetic niche construction (Coninx, 2023).

Microgenetic niche construction involves immediate environmental tweaks that affect real-time interactions, such as organising objects of memory for a task, social synchrony between infants and caregivers, or influencing emotions through interactions with music and art. These alterations are notable for their immediate context and typically do not extend beyond the situation at hand, focussing on how the environment is adapted for a particular moment or activity. On the microgenetic scale, the emphasis is on immediate environmental interactions, independent of the current physical, cognitive, emotional, or social causation. Inheritance at this scale is non-genetically horizontal, passed between individuals of the same generation. Coninx defines as the microgenetic criterion of (mal)adaptation: "Alterations of environmental features are considered adaptive when the corresponding dynamic coordination of a person and their environment enables, facilitates, or enhances their ability to address a local challenge (e.g., memory, emotion regulation, or social understanding)" (Coninx, 2023).

It's important to recognise that the four scales of niche construction, including their specific normative criteria, are not isolated; they typically intersect and influence each other. Each act of niche construction sets in motion feedback loops that create new challenges for (sub)populations, or individuals to respond to and adapt (positive) or maladaptive (negative).

Scale and inter-scale effects of niche construction

As described above, understanding the concepts of adaptation and maladaptation is central to understanding NCDs. Adaptation and maladaptation can also be an expression of a positive or negative niche construction that is dynamic in a spatio-temporal context with different interest groups (stakeholder). The determination of whether a process is adaptive or maladaptive is seldom a clear-cut, binary decision, reflecting the immense complexity involved. Consequently, it can be inferred that niche constructions, may be beneficial or detrimental to specific stakeholders, depending on their activities at various spatio-temporal levels of niche construction. Based on the four spatial and temporal scales, including their normative criteria, basically positive, neutral and negative adjustments can be systematically identified and evaluated. Thus, at least three different models can be determined where positive, neutral and negative (mal)adaptations can occur.

Niche modification at the *same* spatio-temporal level can have positive, neutral and negative effects on the *same* stakeholder due to possibly similar or conflicting interests, concerns and needs (same scale model) of the parties involved. Conversely, in the second model, niche changes at the *same* spatio-temporal level can have positive, neutral and negative effects for *different* stakeholders, due to possibly similar or contradictory interests, concerns and needs (same scale different stakeholder model) of the participants. Finally, in the third model, niche changes at *different* spatio-temporal levels can have positive, neutral and negative effects for the *same* and/or *different* stakeholders (inter-scales model). Both positive and negative reinforcing effects can occur in each model. These effects are significant if they occur under the consideration of the inter-scale model. Self-sustaining cycles of positive and negative effects arise, which can encompass both a spatial-temporal and different levels.

The multi-domain spatio-temporal framework for understanding non-communicable diseases

Here, we present a novel multi-domain spatio-temporal framework (MDST) to systematically describe and investigate NCDs. Our framework integrates the evobiopsychosocial approach (Hunt et al., 2023) and the four scales of niche constructions. The framework (Table 1) classifies data into 12 categories, structured within three domains—biological, psychological, and social. These categories are organised across four spatio-temporal scales of niche construction: phylogenetic, sociogenetic, ontogenetic, and microgenetici). For building the framework, we first understand the original biological an d behavioural domain as questions of cultural evolution without negotiating the biological (genetic) side (Table 1A1). In parallel, we extend the how and why questions to all four niche construction scales (Tables 1A1–D1):

1. How does a physiological or behavioural trait, treatment, aid, or medicine x on niche construction scale A, B, C, D develop over an individual's life? (development).
2. How does x on niche construction scale A, B, C, D work in individuals or groups? (mechanism).
3. Why does x on niche construction scale A, B, C, D help an individual survive, reproduce, and adapt? Why does individual fitness increase? (function).
4. Why did x on niche construction scale A, B, C, D emerge and spread within the population over time? (phylogeny).

Integrating the evobiopsychosocial framework (Hunt et al., 2023) to transfer our extended how and why questions to the psychological domain (Tables 1A2–D2) the following questions arise:

1. How does a psychological behaviour, measure, or treatment x on niche construction scale A, B, C, D develop over an individual's life? (development).
2. How does x on niche construction scale A, B, C, D work in individuals? (mechanism).
3. Why does x on niche construction scale A, B, C, D help an individual succeed or be accepted within a group or population? (function).
4. Why did x on niche construction scale A, B, C, D emerge and spread within a group or the population over time? (phylogeny).

Finally, we transfer the extended questions to the social domain (Tables 1A3–D3):

1. How does a social behaviour or measure x on niche construction scale A, B, C, D develop over an individual's life? (development).
2. How does x on niche construction scale A, B, C, D work in individuals or social groups? (mechanism).
3. Why does this behaviour or measure on niche construction scale A, B, C, D help an individual succeed or be accepted within the social context? (function).
4. Why did x on niche construction scale A, B, C, D emerge and spread within a particular social group, society or population over time? (phylogeny).

The MDST framework yields 48 possible questions in total: 4 from niche construction scales, 3 from domains, and 4 each from "how" and "why" categories. Each of the 12 fields in the table or of the above listed questions can be used as a starting point for systematic and holistic analyses of NCDs. We point out that the priority in an individual study should not necessarily be on the fully completed table, but rather on the systematics for a multimodal method, for which the MDST framework provides an offer. The more questions that can be asked and answered in a field and between fields, the more comprehensive an analysis or treatment approach tends to be. The user can utilise how and why questions as a prompt or reference, as long as these questions are relevant to them. For example, why questions about phylogenetic function at first glance might not seem to be intuitive at the microgenetic niche construction scale (D1, D2), since the microgenetic scale is an individual spatial level. Nevertheless, phylogenetic biological and psychological answers may be possible if (mal)adapted patterns are suspected in certain individual behaviour.

Carrying out an analysis, causal connections and feedback loops can be visually illustrated using a causal map (Figure 1). It can show how certain statements influence each other in the complex framework and help to discover and deepen new cause-effect relationships. Causes can have effects, and the same effects can, represent new causes. This also applies to Tinbergen's questions. In this way, both the framework and a causal map can help to avoid linear-causal argumentation and promote a conceptual, multi-causal, and systemic approach to thinking (Hanisch and Eirdosh, 2021).

Our framework will likely be most informative for common, multifactorial NCDs that have expanded over recent generations—cardiometabolic disease (T2D, obesity, hypertension, ASCVD), chronic respiratory disease (COPD, asthma), behaviour-linked cancers (e.g., lung, colorectal, cervical), chronic musculoskeletal pain, and common chronic mental health conditions—where sociogenetic and ontogenetic processes may dominate exposures and trajectories. For mixed-aetiology NCDs (e.g., autoimmune disorders, neurodegenerative diseases, chronic kidney disease not primarily exposure-driven), MDST may chiefly structure management, equity, and policy rather than primary causal inference. For rare monogenic/chromosomal disorders, cultural–evolutionary mismatch is unlikely to be a major driver of incidence; here MDST might mainly organise care across ontogenetic, microgenetic, and social domains.

Concluding remarks

Understanding and studying NCDs requires an integrative perspective that accounts for their complexity beyond existing models. We integrate biopsychosocial and evolutionary perspectives to show how biological, psychological, and social factors interact across various time and space scales. Integrating niche construction theory into this framework provides a novel lens to examine how (mal)adaptations—both biological and cultural—shape health outcomes. Our multi-domain spatio-temporal framework offers a unique, systematic, multi-causal approach to analysing NCDs within this expanded perspective, allowing for a more comprehensive understanding of adaptation and maladaptation in modern environments. Applying evolutionary insights to public health strategies can enhance prevention and treatment approaches by aligning interventions with both genetic constraints and cultural adaptations. Future research should further explore the applications of this framework, particularly in refining prevention strategies and public health policies that align with both evolutionary constraints and contemporary societal needs.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material. Further inquiries can be directed to the corresponding author.

Author contributions

AL: Methodology, Writing – review & editing, Investigation, Writing – original draft, Conceptualization. UK: Methodology, Writing – original draft, Investigation. BP: Writing – review & editing, Methodology. EP-Z: Investigation, Methodology, Writing – review & editing. DS: Writing – review & editing, Writing – original draft, Methodology, Conceptualization, Investigation.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Correction note

This article has been corrected with minor changes. These changes do not impact the scientific content of the article.

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Glossary

Non-communicable diseases (NCDs)	A group of chronic health conditions that are not caused by infectious agents
Biopsychosocial (BPS) framework	A framework introduced by George Engel in 1977 that emphasises the interaction between biological, psychological, and social factors in understanding health and disease. It contrasts with the traditional biomedical model by integrating mental health, personality, and social influences alongside biological variables, offering a more holistic approach to diagnosing and treating conditions, particularly chronic diseases
Cultural Evolution	The process by which populations of organisms change over generations through mechanisms that extend beyond traditional natural selection and genetic inheritance. It includes also epigenetic changes, developmental processes, social learning, and niche construction in the form of cultural evolution, emphasising the dynamic interactions between organisms and their environments in the course of evolution. Cultural evolution is the dominant evolution for humans. It is much faster than genetic evolution and does not require an increase in fitness. The selection criteria are man-made
Extended Evolutionary Synthesis (EES)	An extension of the Modern Synthesis in evolutionary biology, which includes genetic inheritance as well as non-genetic forms of inheritance, such as culture, as a crucial factor in evolution. EES highlights the role of niche construction in the form of cultural evolution in shaping species
Niche Construction Theory	Recognises that organisms, including humans, shape their environment actively, systematically, and directionally and that this constructed environment as niche constructions (NC) influences evolutionary processes. In humans, this theory highlights the role of culture, technology, and active behaviour in shaping evolutionary outcomes. Niche construction theory is a pillar of EES
Phylogenetic NC	Refers to evolutionary processes and (mal-)adaptations that occur over multiple generations within species or populations, influencing genetic makeup and biological traits in response to environmental changes or (cultural) niche construction. Cultural evolution over a few generations phylogenetically requires no genetic change and no change in fitness
Sociogenetic NC	Pertains to the cultural and social evolution of populations or subpopulations over generations, where non-genetic behaviours and knowledge are transmitted and modified, bypassing slower genetic evolution
Ontogenetic NC	Refers to the development and evolution of an individual's traits, behaviours, and interactions with their environment over their lifetime. This process influences personal health and well-being as shaped by both biological and cultural factors
Microgenetic NC	Relates to the immediate, situational changes and interactions an individual has with their environment, influencing short-term behaviours and adaptations in response to specific contexts or challenges
Biological	Refers to the biological factors involved in chronic diseases, including genetic predisposition, bodily functions, and evolutionary mechanisms that influence disease development and progression
Psychological	Encompasses the mental and emotional aspects of chronic diseases, including individual behaviours, coping mechanisms, emotional responses, and mental health factors that contribute to disease outcomes
Social	Refers to the societal and cultural factors that affect chronic diseases, such as socioeconomic status, social support systems, healthcare access, and cultural beliefs and practices that shape individual and population health outcomes
Social learning	Social learning by imitating or copying each other. In human evolution social learning is more important than individual learning
Mismatches (maladaptation)	Cultural evolution leads to evolutionary mismatches in the form of infectious and non-infectious diseases, which can occur repeatedly or intensify in each generation. They are culturally inherited. Biological and cultural evolution together can explain the causes of mismatches. The mismatches caused by cultural evolution, for example chronic back pain caused by predominantly sedentary behaviour can be exposed to new selection forces that can only lead to new genetic adaptations in the long term. In addition, in cultural evolution, the focus shifts beyond biological survival and genetic transmission. Maladaptation can also bring social, technological, or cultural disadvantages.