PHARMACOKINETIC CYCLING SYSTEM

Domain Model & Systems Architecture

Nomad Nutrients · Internal Design Document · v1.0

Document scope: This document defines the first-class entities that power the Nomad Nutrients cycling engine — the pharmacokinetic-aware system that determines when each compound is taken, when it rests, and what swaps in during the off period. It is the canonical reference for how the domain model maps to Shopify metafields, storefront UX, and customer-facing education.

Audience: Solo founder/developer (Tanner), future technical collaborators, and the AI systems (Claude Code CLI, daily standup) that reference this as a context anchor.

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1. Core Design Principle

> *Your body adapts to everything — that's the whole point of biology. The cycling system exists because some compounds target biological systems that adapt (receptors, enzymes, neuroendocrine axes), and some target systems that don't (substrates, cofactors, structural materials). The entire architecture derives from this one distinction.*

The Nomad Nutrients cycling engine is not a marketing gimmick or a precautionary measure. It is a pharmacokinetic scheduling system that models the adaptation kinetics of each compound's biological target and derives the optimal on/off cadence from first principles. Every decision in this system — whether a compound is daily, pulsed, or macro-cycled — traces back to a specific receptor, enzyme, or axis and its measured or estimated recovery time constant.

This matters commercially because it creates the true product moat: Smart Stack pre-ships mechanism-swap products during off-phases so the customer's wellness goal is never interrupted, even while the biology resets. The swap-pair logic is a derived relationship, not a manual mapping — it falls naturally out of the pathway architecture defined in this document.

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2. Entity Definitions

The cycling system is built on nine first-class entities. Each has a clear boundary, a reason for existing as a separate concept, and a defined relationship to the others. The order below follows the causal chain: compounds act on target systems, which adapt via specific mechanisms, which recover on specific timelines, along specific pathways, toward specific goals, packaged as products, scheduled by protocols, and paired for swaps.

2.1 Compound

Definition: The bioactive molecule or molecular complex that produces the pharmacological effect. This is the atomic unit of the system — everything else derives from what the compound does biologically.

Examples: Caffeine, Withaferin A (from ashwagandha), cordycepin (from cordyceps), hericenone (from lion's mane), thymoquinone (from black seed oil).

Why it's separate from Product: A single product (SKU) may contain multiple compounds (e.g., the L-theanine + caffeine stack contains two distinct compounds with different target systems). Cycling logic operates at the compound level, not the product level. A product inherits the most restrictive cycling requirement of its constituent compounds.

Field	Type	Description
slug	string	URL-safe identifier (e.g., 'huperzine-a')
name	string	Display name (e.g., 'Huperzine A')
source	string	Natural source organism or synthesis (e.g., 'Huperzia serrata')
halfLife	string | null	Pharmacokinetic half-life if known (e.g., '~24 hours')
targetSystems	TargetSystem[]	All biological targets this compound acts on
pathways	BiologicalPathway[]	The specific routes to wellness goals

2.2 Target System

Definition: The specific receptor, enzyme, transporter, or neuroendocrine axis that a compound directly modulates. This is the entity that adapts (or doesn't) and therefore determines whether cycling is needed.

Examples: Adenosine A1/A2A receptors, acetylcholinesterase (AChE) enzyme, HPA axis (CRH/ACTH/cortisol feedback loop), TrkA receptor, GABA-A receptor, Keap1-Nrf2 signaling complex, SLC6A8 creatine transporter.

Critical distinction: A target system is not the same as a wellness goal or a pathway. The adenosine A1/A2A receptor is a target system. 'Cognitive alertness via adenosine blockade' is a pathway. 'Focus' is a goal. This separation is what makes the swap-pair logic possible.

Field	Type	Description
slug	string	Identifier (e.g., 'adenosine-a1-a2a')
name	string	Full pharmacological name
type	enum	'receptor' | 'enzyme' | 'transporter' | 'axis' | 'signaling_complex' | 'substrate_pool'
adapts	boolean	Whether this system develops tolerance with sustained exposure. The single most important field in the model.
adaptationMechanism	AdaptationMechanism | null	How adaptation manifests (null if adapts = false)

resetProfile	ResetProfile | null	Recovery kinetics during the off period (null if adapts = false)

2.3 Adaptation Mechanism

Definition: The specific biological process by which a target system develops tolerance to sustained compound exposure. This answers the question: how does the body fight back?

Understanding the adaptation mechanism is essential because it determines both whether cycling is needed and what kind of cycling is appropriate. A receptor that internalizes in 48 hours needs a different protocol than an axis that drifts its set-point over 8 weeks.

Mechanism Type	Description & Examples
Receptor downregulation	Cell surface receptor density decreases in response to chronic agonist exposure. Receptors are internalized via endocytosis or gene expression of receptor subunits is reduced. E.g., adenosine A1/A2A (caffeine), MT1/MT2 (melatonin), 5-HT1A/2A (5-HTP).
Receptor internalization	A subset of downregulation where receptors are physically pulled from the membrane into endosomes. Faster than transcriptional downregulation. E.g., GABA-A receptor internalization via clathrin-mediated endocytosis.
Enzyme upregulation	The body synthesizes more of the enzyme a compound inhibits, compensating for the block. E.g., AChE enzyme synthesis increases during sustained Huperzine A exposure.
Feedback loop desensitization	A signaling cascade's sensitivity to its own activation decreases. The pathway still fires, but the downstream response attenuates. E.g., Keap1-Nrf2-ARE feedback blunting (black seed oil, moringa), GCL feedback inhibition (NAC).
Axis set-point drift	A neuroendocrine axis (HPA, HPG) recalibrates its homeostatic set-point to accommodate the assisted baseline. The slowest form of adaptation, requiring weeks to develop and weeks to reverse. E.g., HPA axis cortisol set-point (ashwagandha), HPG axis GnRH pulsatility (tongkat ali).
Substrate competition	An exogenous precursor competes with other substrates for a shared enzyme, creating an imbalance. E.g., 5-HTP competing with L-DOPA for AADC, depleting dopamine/norepinephrine relative to serotonin.
Cofactor depletion	A compound's mechanism consumes an endogenous cofactor faster than it can be replenished. E.g., resveratrol depleting NAD+ via sustained SIRT1 activation.
Immune polarization drift	Sustained immunomodulation shifts the macrophage M1/M2 balance or NK cell responsiveness beyond the intended range.

	E.g., reishi shifting toward immunosuppressive M2 bias over 8+ weeks.

2.4 Reset Profile

Definition: The recovery kinetics of a target system during the off period. This answers: what happens during rest, and how long does it take? The reset profile is the entity that directly determines cycling category (A, B, or C) and off-period duration.

Field	Type	Description
timeConstant	string	Estimated time for the target system to reach ~63% recovery (e.g., '~48 hours', '2–3 weeks')
fullResetDuration	string	Estimated time for full (95%+) recovery
whatResets	string	Plain-language description of the biological process during off period
evidenceQuality	enum	'clinical' | 'preclinical' | 'mechanistic_inference' — how confident we are in the timing

The distinction between timeConstant and fullResetDuration matters operationally. The cycling protocol uses the timeConstant to set the minimum off period (enough for meaningful recovery), while fullResetDuration informs whether a longer break might be beneficial periodically. Category B compounds have time constants under 72 hours. Category C compounds have time constants measured in weeks.

2.5 Biological Pathway

Definition: The specific biological route a compound takes to achieve a wellness goal. This is the critical entity that most supplement brands do not model — and the one that makes swap pairs derivable rather than manually curated.

> *Two compounds share a wellness goal but use different pathways when they act on non-overlapping target systems. This is the formal definition of a valid swap pair. Ashwagandha reaches 'Calm' via HPA axis modulation. GABA + Theanine reaches 'Calm' via GABAergic signaling. Same goal, non-overlapping pathway — valid swap.*

Field	Type	Description
slug	string	Identifier (e.g., 'hpa-cortisol-modulation')
name	string	Descriptive name (e.g., 'HPA axis cortisol modulation')

targetSystems	TargetSystem[]	Which target systems this pathway passes through
goal	WellnessGoal	The wellness goal this pathway serves
compounds	Compound[]	Which compounds use this pathway

Overlap rule: Two pathways overlap if they share any target system. Overlapping pathways cannot form a swap pair, because the off period for one compound would not provide rest for the shared target. This is the constraint that catches the moringa/black-seed-oil Nrf2 conflict identified earlier.

2.6 Wellness Goal

Definition: The customer-facing outcome category. This is what the customer selects and what remains constant through cycling and swaps. The brand tagline is: 'Choose your wellness goal, we take care of the rest.'

Goal	Consumer Description	Biological Domain
Energy	Sustained physical and mental energy	Mitochondrial function, ATP production, adrenal output, oxygen utilization
Focus	Clarity, concentration, cognitive performance	Cholinergic signaling, dopaminergic tone, adenosine modulation, BDNF/NGF
Calm	Stress resilience, relaxation without sedation	HPA axis, GABAergic signaling, serotonergic balance
Sleep	Deep, restorative sleep	Melatonergic signaling, GABA tone, circadian rhythm regulation
Recovery	Physical repair, inflammation management	NF-κB/COX-2 modulation, antioxidant defense (Nrf2), collagen synthesis
Beauty	Skin, hair, nail health from within	Collagen synthesis, antioxidant protection, micronutrient supply

The six-goal taxonomy is fixed. New products are classified into existing goals, not the reverse. If a compound serves multiple goals, it has multiple pathways — one per goal.

2.7 Product

Definition: The sellable SKU — what ships in a box and appears in the Shopify catalog. A product contains one or more compounds and belongs to one primary wellness goal. The product inherits its cycling protocol from its most restrictive compound.

Field	Type	Description
sku	string	Shopify product identifier
name	string	Customer-facing product name
compounds	Compound[]	All bioactive compounds in this product
primaryGoal	WellnessGoal	The goal this product is categorized under
cyclingProtocol	CyclingProtocol	Derived: the most restrictive protocol of any compound
category	'A' | 'B' | 'C'	Derived from cyclingProtocol (A=daily, B=pulsed, C=macro-cycle)

Inheritance rule: If a product contains one Category A compound and one Category B compound, the product is Category B. If it contains one B and one C, it is Category C. The most restrictive compound determines the product's cycling behavior. This ensures no target system is over-exposed.

2.8 Cycling Protocol

Definition: The specific on/off schedule derived from a compound's reset profile. This is the operational output of the pharmacokinetic model — the actual calendar the customer follows.

Category	On Period	Off Period	Derivation
A Daily	Continuous	None	Target system does not adapt (adapts = false)
B Pulsed	5 days/week	2 days/week	Reset time constant < 72 hours
C Macro-cycle	4–12 weeks	2–4 weeks	Reset time constant > 1 week (axis/immune drift)

Category B's 5/2 cadence aligns with the work week, which is a UX bonus but not the reason for the split. The pharmacokinetic reason is that the relevant receptors and enzymes measurably recover

within 48 hours. Category C's variable durations (8 on/2 off vs. 12 on/4 off) reflect the different recovery rates of neuroendocrine axes vs. receptor systems vs. immune polarization.

2.9 Swap Pair

Definition: A relationship between two products that share a wellness goal but use non-overlapping biological pathways. During one product's off period, its swap partner takes over — maintaining the customer's wellness goal through a completely different mechanism, giving the first product's target systems full biological rest.

> *This is the moat. Any brand can sell ashwagandha. Any brand can say 'cycle it.' Only Nomad Nutrients automatically ships you the right swap product at the right time, curated to hit the same wellness goal through a different pathway so there's zero gap in your results.*

Field	Type	Description
productA	Product	The primary product (on-cycle)
productB	Product	The swap product (fills the off-cycle)
sharedGoal	WellnessGoal	The wellness goal both serve
pathwayOverlap	boolean	Must be false — validated at creation. If true, pair is invalid.
direction	'bidirectional' | 'a_to_b'	Whether B also cycles off and swaps to A

3. Entity Relationship Map

The causal chain flows left-to-right: Compounds act on Target Systems, which may Adapt via specific Mechanisms, which Recover according to Reset Profiles. This determines the Cycling Protocol. Compounds reach Wellness Goals via Biological Pathways, and pathway non-overlap enables Swap Pairs between Products.

Compound → acts on → **Target System** → adapts via → **Adaptation Mechanism** → recovers per → **Reset Profile** → determines → **Cycling Protocol**

Compound → reaches goal via → **Biological Pathway** → serves → **Wellness Goal**

Product → contains → **Compound[]** → inherits most restrictive → **Cycling Protocol**

Swap Pair = two **Products** sharing a **Wellness Goal** with zero **Pathway** overlap

Key cardinalities: A compound can act on multiple target systems (e.g., bacopa modulates 5-HT_3, AChR, and BDNF). A target system can be acted upon by multiple compounds (e.g., both alpha-GPC and huperzine-A affect the cholinergic system, though via different mechanisms). A product belongs to one primary goal but a compound may serve multiple goals via separate pathways.

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4. Cycling Category Derivation Logic

The cycling category is not assigned manually. It is derived algorithmically from the properties of the compound's target systems. The decision tree is:

Step 1 — Does any target system adapt? If adapts = false for all target systems, the compound is Category A (daily). No further analysis needed. This covers substrates (creatine), cofactors (magnesium, D3+K2), structural materials (collagen, omega-3), and osmolytes (taurine, electrolytes).

Step 2 — What is the reset time constant? If any target system adapts = true, check the reset profile's timeConstant for each adapting system. Take the longest one (the bottleneck).

Step 3 — Apply the threshold: If the longest timeConstant is ≤72 hours, the compound is Category B (pulsed, 5 on / 2 off). If the longest timeConstant is >1 week, the compound is Category C (macro-cycle). The specific on/off durations for Category C are set by the fullResetDuration of the slowest-recovering target system.

This derivation is deterministic. Given the same target system properties, the same category always results. When a new compound is added to the catalog, populating its target systems and their adaptation properties automatically assigns its cycling category.

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5. Swap Pair Derivation Rules

A valid swap pair must satisfy all three conditions:

Rule 1 — Same goal: Both products must share the same primary wellness goal. A Focus product can only swap with another Focus product.

Rule 2 — Non-overlapping pathways: The target systems used by Product A's compounds must have zero intersection with the target systems used by Product B's compounds. If they share even one target system, the swap fails — the off period wouldn't provide rest for that shared system.

Rule 3 — At least one is Category C: Swap pairs are only operationally meaningful for macro-cycled products. Category B products already get their rest within each week. Category A products don't need rest at all. Swaps exist to fill the multi-week gap that Category C products create.

Validation example — moringa and black seed oil: Both are Category C, both serve Recovery. However, moringa's pathway uses the Keap1-Nrf2-ARE signaling complex as a target system. Black seed oil also uses Keap1-Nrf2-ARE. They share a target system, violating Rule 2. These two are NOT valid swap partners despite serving the same goal. The off period for one would not rest the Nrf2 system if the other is active.

Valid example — ashwagandha and GABA+theanine: Ashwagandha reaches Calm via HPA axis cortisol modulation. GABA+Theanine reaches Calm via GABAergic signaling. Zero shared target systems. Ashwagandha's off period provides full HPA axis rest while GABA+Theanine maintains the Calm goal through a completely different mechanism.

6. Shopify Data Model Mapping

All cycling system state lives in Shopify metafields under two namespaces. This avoids external databases and keeps the single source of truth in the commerce platform.

Product Metafields (nomad_cycling namespace)

Metafield Key	Type	Description
`cycling_category`	single_line_text	'A' | 'B' | 'C'
`on_period_days`	number_integer	Days in the on-cycle (null for Category A)
`off_period_days`	number_integer	Days in the off-cycle (null for Category A)
`compounds_json`	json	Full compound data array (target systems, pathways, rationale)
`swap_partner_ids`	list.product_reference	Valid swap partner product references
`why_it_cycles`	multi_line_text	Consumer-facing cycling rationale
`off_period_effect`	multi_line_text	Consumer-facing off-period explanation
`driving_mechanism`	single_line_text	Short mechanism label for UI tags

Customer Metafields (nomad_curations namespace)

Metafield Key	Type	Description
`active_cycles`	json	Current cycling state per product (on/off, day count, swap phase)
`pending_swaps`	json	Upcoming swap events for next shipment
`swap_history`	json	Log of past swap events for dashboard display
`opt_out_swaps`	list.product_reference	Products the customer has declined as swaps

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7. Consumer-Facing Language Guide

The pharmacological precision of this system is an internal advantage. Consumer-facing communication translates the science into intuitive language without losing accuracy. The following translations are canonical:

Internal Term	Consumer-Facing Language
Receptor downregulation	'Your body adapts to it, so we cycle it to keep it working'
Adaptation mechanism	'Your body's natural adjustment'
Reset profile / recovery	'The reset period' or 'what resets during the break'
Target system	'The biological system it works through'
Non-overlapping pathway	'A different biological route to the same result'
Swap pair	'Your Smart Stack swap' or 'your mechanism-match product'
Cycling protocol	'Your cycling schedule'
Category A / B / C	'Daily' / 'Pulsed (5 days on, 2 off)' / 'Cycled (with smart swap)'
Pharmacokinetic cycling	'Science-backed cycling' or 'the Nomad cycling system'

The driving mechanism field on each compound is shown to consumers as a monospace tag (e.g., 'AChE turnover / M1 receptor resensitization'). This is intentionally technical — it signals depth and credibility to the ICP (health-conscious remote knowledge workers) without requiring them to understand it. The whyItCycles and offPeriodEffect fields provide the accessible explanation.

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8. Constraints & Edge Cases

8.1 Shared-pathway conflict

When two Category C products share a target system, they cannot swap for each other. But they might both need to cycle off simultaneously. If a customer's stack contains both moringa and black seed oil (both Nrf2-pathway), the system must ensure they cycle together, not alternately. The off period must rest Nrf2 from both compounds. This means co-scheduling their off periods and finding a non-Nrf2 Recovery product to fill the gap.

8.2 Multi-goal compounds

Some compounds serve multiple wellness goals via different pathways. Ashwagandha, for example, could serve both Calm (HPA axis) and Recovery (anti-inflammatory). The product is assigned one primary goal for catalog purposes, but the pathway data supports future features like cross-goal swap recommendations.

8.3 Category B products in stacks with Category C

If a customer's stack contains both B and C products targeting the same goal, the B product continues its weekly 5/2 cadence even during the C product's multi-week off period. The B product is not a 'swap' for the C product — it's a constant baseline. The swap fills only the C-shaped gap.

8.4 Evidence quality transparency

Some reset profiles are backed by clinical trial data (caffeine/adenosine receptor kinetics are well-studied). Others rely on mechanistic inference from preclinical data (e.g., TrkA desensitization timing for lion's mane is extrapolated from NGF receptor studies, not lion's mane-specific trials). The evidenceQuality field on ResetProfile tracks this honestly. Consumer-facing content should not overstate confidence.

8.5 Customer opt-out model

The Smart Stack operates on an opt-out basis: 'We curate, you approve.' Swap suggestions are generated by the system and surfaced via email reveal + dashboard moment. The customer can decline specific swap products (stored in opt_out_swaps metafield), at which point the system selects the next valid swap partner by pathway non-overlap. If no valid swaps remain, the customer is notified that they'll have a gap period and given the option to manually select.