FOUNDATIONAL WHITEPAPER · VERSION 1.0

Bio-Optimized Leadership™

A foundational model of Biological Capacity, leadership performance, and outcomes across longer working lives

Bio-Optimized Leadership explains how modifiable and contextual drivers shape a leader's Biological Capacity, and how that capacity influences the quality and sustainability of leadership performance and downstream individual, team, and organizational outcomes through multiple pathways.

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Date 24 July 2026

DOI 10.5281/zenodo.21538567

Version 1.0

Website biooptimizedleadership.com

Abstract

Bio-Optimized Leadership™ (BOL™) is a leadership and organizational-performance model that treats the Biological Capacity available to leaders as a modifiable input to sustained judgment, behavior, adaptation, and performance in demanding environments. It organizes the relationship as **Drivers → Biological Capacity → Outcomes**, while recognizing multiple mediating pathways, context, and different timescales. Biological Capacity is defined as the integrated cognitive, psychological, and physiological capacity a person can draw on to generate, sustain, and recover from demanding work over time. It is assessed through domain-relevant measures and the properties **Level · Reserve · Recovery**. Biological age is positioned as an important measure within Physiological Capacity, not as a proxy for the whole construct.

The paper links the four BOL driver categories - Lifestyle; Environment; Technology & AI; and Psychological & Behavioral - to immediate and accumulated effects, aging biology, physiological reserve, and capacity trajectories. It distinguishes evidence established outside BOL from BOL interpretation and hypotheses. Leadership behavior and other mediators are retained as explanatory pathways without becoming official model pillars. The paper also introduces a Workspan proposition: Biological Capacity contributes directly to outcomes and may moderate both the continued accumulation and the deployment of Experience Capital. This interaction, and the proposition that preserving capacity can extend domain-specific Peakspan and support longer Workspan, remain testable hypotheses rather than validated BOL intervention effects.

Contents

SECTION 1

Why Biological Capacity belongs in leadership

Leadership models commonly foreground strategy, skills, personality, experience, behavior, and context. BOL adds a more upstream model: it makes explicit the biological capacity available to the person who must use those resources.

A leader can possess relevant knowledge, authority, and experience while varying substantially in the capacity available to attend, learn, regulate emotion and behavior, integrate information, make decisions, sustain effort, and recover. Some of that variation is temporary. Some reflects a more stable reference level, reserve, recovery pattern, or longer-term trajectory. BOL makes this capacity explicit so that it can be defined, measured, challenged, and developed rather than treated as invisible background.

This does not reduce leadership to biology. Performance and organizational outcomes are multiply determined. Role demands, team capability, incentives, culture, strategy, market conditions, chance, and many other variables matter. BOL's narrower claim is that Biological Capacity is an important and potentially modifiable input whose omission leaves leadership and performance models incomplete.

> **SCOPE BOUNDARY**
>
> The BOL model is an organizing and research framework. The complete Drivers → Biological Capacity → Outcomes chain has not yet been validated as one integrated causal model, and no single measure currently represents the whole of Biological Capacity.

Adjacent scientific frameworks make the model plausible and researchable. The World Health Organization distinguishes a person's intrinsic capacity from environment and functional ability.[1,2] Geroscience and resilience research distinguish baseline function, reserve, challenge response, and recovery.[3,4] The hallmarks of aging offer a mechanistic framework for longer-term biological change.[5] Cognitive-reserve research shows why similar observable pathology or change can produce different functional outcomes.[6] BOL draws on these lineages while making a distinct leadership and work-performance proposition.

Drivers → Biological Capacity → Outcomes

SECTION 2

Provenance and development

The Bio-Optimized Leadership model has a documented development trail. It originated as *Vibrant Leadership* in 2022, when the model connected lifestyle and environmental inputs, biological aging, leadership performance, and downstream outcomes. The name **Bio-Optimized Leadership** was documented in 2024 and the ™ designation has been used since November 2024. During 2025 and 2026, the model was refined around Biological Capacity as the central construct and connected more explicitly to geroscience, intrinsic capacity, reserve, recovery, Peakspan, and longer working lives.

Date	Documented development	What it establishes
17 May 2022	*Leading Into 2050 with Vibrant Leadership*	Early model linking drivers, biological aging, leadership performance, and multilevel outcomes.
30 April 2024	Leadership timeline	First documented use of the name **Bio-Optimized Leadership**.
19 November 2024	Leadership timeline update	First documented use of **Bio-Optimized Leadership™** and **Bio-Optimized Leader™**.
2025-2026	Whitepaper drafts and research memoranda	Development of Biological Capacity, the three dimensions, Level · Reserve · Recovery, and the Workspan proposition.
24 July 2026	Foundational Whitepaper v1.0	First complete edition consolidating the architecture, definitions, evidence boundaries, and testable research propositions.

The development trail establishes authorship and evolution of the BOL model. It does not imply ownership of the external scientific constructs incorporated into it. Intrinsic capacity, physiological and cognitive reserve, the hallmarks of aging, allostatic load, successful aging, and Peakspan each have independent intellectual lineages.

SECTION 3

The foundational architecture

Bio-Optimized Leadership is a leadership and organizational-performance model that treats the biological capacity available to leaders as a modifiable input to sustained judgment, behavior, adaptation, and performance in demanding environments.

Biological Capacity is the integrated cognitive, psychological, and physiological capacity a person can draw on to generate, sustain, and recover from demanding work over time.

Drivers

Conditions and exposures that can support, strain, build, maintain, or erode capacity across different timescales.

Biological Capacity

The integrated capacity available for demanding work and recovery, organized into three interdependent dimensions.

Outcomes

Individual, team, and organizational consequences reached through multiple mediators, moderators, and contextual pathways.

The outcome side of the model shows a proposed **performance cascade**: effects expressed at the individual level may propagate through leadership behavior, interaction, and other pathways to team outcomes and, over time, organizational performance. This is not automatic aggregation or a deterministic, immediate, unidirectional, or mediator-free causal chain. At each downstream level, contextual influences, time lags, feedback, and alternative explanations increase. For example, organizational conditions can also alter workload, autonomy, sleep opportunity, social relationships, and other drivers.

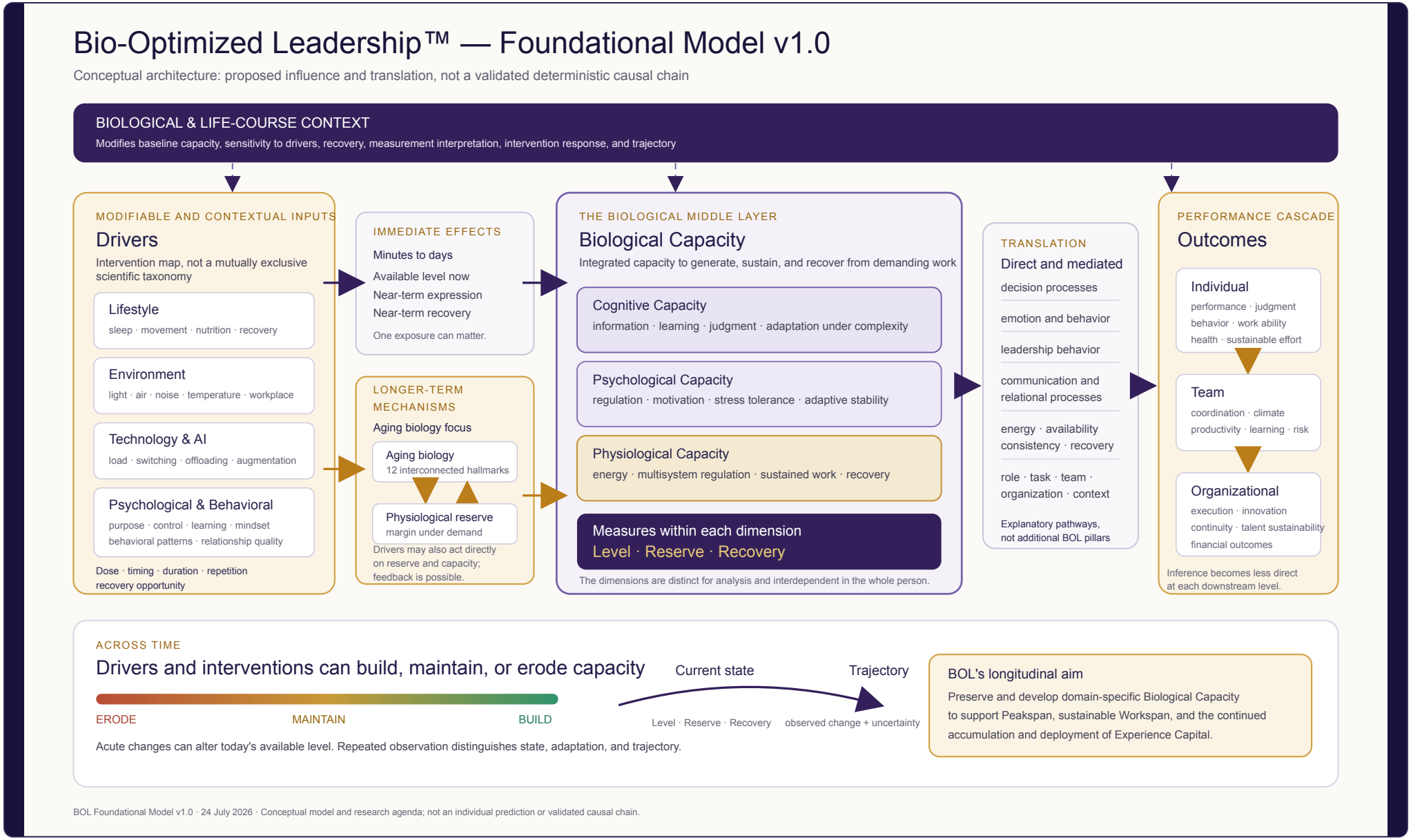


Figure 1. The Bio-Optimized Leadership foundational model, v1.0. Four driver categories operate across immediate and accumulated timescales. The longer-term mechanism highlights aging biology and physiological reserve as reciprocal research layers; drivers may also affect reserve and capacity directly, and feedback is possible. Biological & Life-Course Context modifies drivers, capacity, measurement, and response. Cognitive, Psychological, and Physiological Capacity are interdependent and examined through Level · Reserve · Recovery. Capacity reaches a proposed performance cascade of individual, team, and organizational outcomes directly and through mediators, with inference less direct at each downstream level. Intervention can build, maintain, or reduce erosion across time. Experience Capital remains in the secondary Workspan figure rather than becoming a fourth capacity pillar.

SECTION 4

Drivers, time, intervention, and context

4.1 Four driver categories

Lifestyle

Sleep, physical activity, nutrition, recovery practices, substance exposure, and related patterns.

Environment

Light and circadian conditions, air, noise, temperature, nature, travel, workplace design, and social environment.

Technology & AI

Information load, interruption and switching, cognitive offloading or augmentation, decision cadence, surveillance, and recovery-boundary effects.

Psychological & Behavioral

Purpose, perceived control, learning, mindset, behavioral patterns, and relationship quality.

These categories are intervention maps, not mutually exclusive scientific taxonomies. One exposure can sit across categories, affect several capacity dimensions, and operate through more than one biological or behavioral mechanism. Direction cannot be inferred from a category alone. Dose, timing, duration, repetition, recovery opportunity, individual context, and interaction with other drivers all matter.

4.2 Immediate and accumulated effects

BOL separates **timescale** from **type of effect**. Acute and chronic describe exposure patterns; they are not two isolated pathways.

Effect	What may change	Interpretive boundary
Immediate state and expression	Capacity level available over minutes or days; near-term expression and recovery.	A temporary state change is not automatically a durable shift in underlying capacity.
Accumulation and adaptation	Reference level, reserve, recovery, and trajectory after repeated, clustered, or sustained exposure.	Repeated acute events may accumulate before they would normally be called chronic.

A single night of restricted sleep illustrates the distinction. A 2024 meta-analysis of 44 studies found that restricting one night's sleep opportunity to two to six hours increased subjective sleepiness and impaired sustained attention, including attentional lapses and increased reaction times.[7] This supports an immediate driver-to-capacity effect. It does not show that one night permanently erodes Biological Capacity. Longer-term change requires evidence about repetition, adaptation, recovery, and trajectory.

4.3 Intervention: build, maintain, or erode

Intervention is the deliberate act of changing a driver, exposure, biological mechanism, or recovery condition so that it is more likely to **build**, **maintain**, or less severely **erode** Biological Capacity. An intervention can act at different points in the model and may influence one measure while leaving another unchanged.

ESTABLISHED COMPONENT EVIDENCE

The U.S. POINTER randomized clinical trial identifying the impact of multidomain lifestyle interventions found improvement in global cognition in both lifestyle groups and a statistically significant relative advantage for the more structured intervention over two years in older adults at elevated risk of cognitive decline.[8] It does not establish effects in healthy midlife leaders or workplaces, though.

4.4 Biological & Life-Course Context

Age, sex, genetics, reproductive stage, menopause, prior illness or injury, disability, developmental history, and similar conditions can shape baseline capacity, sensitivity to drivers, reserve, recovery, measurement interpretation, intervention response, and likely trajectory. They are neither lifestyle choices nor fixed outcome penalties. BOL treats them as an official modifying layer rather than a fifth driver.

SECTION 5

Aging biology and physiological reserve

For cumulative and longer-term change, BOL focuses here on aging biology and multi-system physiological reserve as interacting mechanisms within the wider driver-to-capacity system. This is a research focus, not a claim that the model is a simple one-way chain.

Drivers → aging biology / hallmarks ↔ physiological reserve → **Biological Capacity**

Drivers may also affect reserve and capacity directly; feedback can occur across the system.

The expanded hallmarks framework describes 12 interconnected features of aging: genomic instability, telomere attrition, epigenetic alterations, loss of proteostasis, disabled macroautophagy, deregulated nutrient sensing, mitochondrial dysfunction, cellular senescence, stem-cell exhaustion, altered intercellular communication, chronic inflammation, and dysbiosis.[5] BOL uses these hallmarks as a mechanistic research layer. It does not claim that every driver acts on every hallmark, that any one hallmark maps directly to leadership performance, or that a transient molecular response is equivalent to changed biological aging.

Physiological reserve is the margin available across interacting systems to respond to demand, maintain function, and recover. Reduced reserve can narrow the ability to absorb additional load before overt disease or disability becomes visible. NIA workshop work emphasizes perturbation-response trajectories and repeated observation when assessing physiological resilience.[3] A systematic review of physical resilience likewise centers resistance to or recovery from functional decline after a stressor.[4]

Allostatic-load theory offers an additional bridge between repeated demand and cumulative physiological burden: protective stress mediators can become damaging when repeatedly activated, insufficiently shut off, or otherwise dysregulated.[9] BOL does not equate allostatic load with Psychological Capacity or with the whole capacity construct. It uses the theory to clarify why exposure, adaptation, and recovery history matter.

IMPORTANT DISTINCTION

Reserve is not simply a high resting score. It is the margin available under additional demand. Recovery is not simply feeling better. It includes the speed, completeness, and stability of return toward an appropriate baseline after a defined challenge.

SECTION 6

The three dimensions of Biological Capacity

Humans are integrated systems. BOL's three dimensions are analytically distinguishable, allowing each to be defined and measured, but they remain biologically and behaviorally interdependent.

6.1 Cognitive Capacity

Definition: the capacity to acquire, hold, manipulate, integrate, and apply information in order to think, learn, decide, and adapt under complexity and uncertainty.

Candidate components and measures: attention and vigilance; processing speed; working memory; executive function; flexibility and inhibition; metacognition; performance under cognitive load; and brain-age or cognitive-age measures where scientifically appropriate.

Model role: Cognitive Capacity is most proximal to complex judgment and high-stakes leadership performance. This does not make it independent of, or categorically more important than, the other dimensions.

6.2 Psychological Capacity

Definition: the capacity to regulate emotion and behavior, sustain motivation, tolerate stress, and remain adaptive and sufficiently stable under pressure.

Candidate components and measures: emotion regulation; stress tolerance and perceived coping capacity; psychological flexibility; motivation and self-regulation; affective stability; validated measures of burnout, resilience, or psychological functioning; and responses to standardized stressors.

Model role: Psychological Capacity regulates how Biological Capacity is expressed and sustained under pressure and during adaptation.

6.3 Physiological Capacity

Definition: the integrated capacity of the body's physiological systems to produce energy, sustain physical and mental work, maintain regulation under load, and recover.

Candidate components and measures: cardiorespiratory fitness; metabolic regulation; immune function; musculoskeletal strength and function; sleep and circadian function; autonomic balance; endocrine function; energy and fatigue; biological age; and system-specific or organ-specific aging measures.

Model role: Physiological Capacity is the biological foundation supporting the system. The plain-language phrase *physical vitality, energy, resilience, and recovery* may aid communication, but the official construct name is **Physiological Capacity**.

Empirical work on intrinsic capacity supports studying multidimensional capacity as an overall construct with subdomains, while keeping environment and functional ability distinct.[2] That research does not validate BOL's three-dimension structure or a leader-specific instrument. BOL's architecture must therefore be treated as a model decision requiring measurement development and construct validation.

SECTION 7

Measurement: Level · Reserve · Recovery

Biological Capacity is not one measure. Each dimension requires a multimodal set of domain-relevant measures. Some measures may inform more than one dimension, but their placement and interpretation must be explicit.

Level

What level is available now under defined conditions?

A current observation may reflect sleep, time of day, recent stressors, illness, practice effects, and measurement conditions.

Reserve

How much additional demand can be absorbed before performance or regulation deteriorates?

Reserve generally requires a challenge, load-response curve, or another defensible estimate of margin.

Recovery

How quickly, completely, and stably does the measure return toward baseline after demand?

Recovery requires a defined stressor and repeated post-demand observation.

7.1 Current level versus reference level

An observed level can fluctuate with acute conditions. A more stable **reference level** requires repeated measurement under standardized or well-characterized conditions. This avoids turning a temporary state change into a false claim about enduring capacity. Within-person variation may itself be informative, particularly when linked to specific drivers and outcomes.

7.2 Trajectory and prediction

Repeated observations can establish observed change. Statistical models may estimate trajectory and, where prospectively validated, predict likely future capacity with uncertainty. BOL must distinguish five different statements:

1. an observed current state;
2. an observed change over time;
3. a model-estimated trajectory;
4. a prospectively validated prediction with uncertainty; and
5. a BOL hypothesis.

MEASUREMENT PROPOSITION

A future BOL measurement system should retain dimension-level and property-level information before considering any composite score. A high resting level cannot substitute automatically for reserve, and neither can substitute for recovery.

SECTION 8

Biological age within the model

Biological age is one measure within **Physiological Capacity**. It attempts to summarize aspects of aging biology that chronological age cannot capture, but it does not measure the whole of Physiological Capacity or

Biological Capacity.

- General biological-age tests sit primarily within Physiological Capacity.
- Specialized brain-age or cognitive-age measures sit primarily within Cognitive Capacity.
- Biological-age measures may inform level and longer-term trajectory, depending on what a clock actually measures and how it has been validated.
- Reserve and recovery normally require additional dynamic or challenge-based measures.
- Different clocks measure different biological features and are not interchangeable.

A comprehensive review of aging biomarkers concludes that clocks and biomarker classes remain heterogeneous and that links to physiology, function, standardization, and practical interpretation require further work.[10] BOL therefore rejects the idea that one clock score can represent the whole person or establish an individual's capacity to lead.

Biological age may become increasingly useful for performance, Peakspan, Workspan, and Healthspan research. That is a development direction, not a fully validated BOL conclusion. Its value will depend on whether a specific measure adds reliable, prospective information beyond chronological age and direct functional measures for the decision at hand.

SECTION 9

Pathways from capacity to outcomes

Biological Capacity may affect outcomes through cognitive performance, emotion and behavior regulation, leadership behavior, communication and interpersonal effects, energy and availability, consistency, recovery, engagement, team climate, coordination, trust, job design, and organizational conditions. These pathways are important precisely because the model does not assume a direct, mediator-free route from a biomarker to a business KPI.

Individual

Attention, judgment, decision quality, adaptability, regulation, energy, sustainable effort, recovery, health, absence, work ability, engagement, and leadership behavior.

Team

Engagement, climate, coordination, execution, adaptability, learning, productivity, quality, innovation, error, and risk.

Organization

Execution, strategic adaptation, innovation, productivity, quality, continuity, talent sustainability, financial outcomes, and growth.

The farther an outcome sits from an individual capacity measure, the more mediators, moderators, contextual influences, time lags, and alternative explanations must be expected. Financial and organizational KPIs require especially strong attribution controls.

9.1 What leader-specific studies currently show

Leader sleep studies illustrate why mediation belongs inside the explanatory chain. A ten-day experience-sampling study found an indirect pathway from leader sleep quality through ego depletion and abusive

supervision to work-unit engagement; sleep quantity did not carry the reported indirect effect.[11] Two laboratory experiments found that leader sleep deprivation harmed follower ratings of charismatic leadership through deep acting, while a second experiment examined sleep-deprived followers' attributions.[12] These studies support behavior and perception as pathways. They do not establish team or firm performance effects.

In 156 Swedish CEOs, self-reported burnout was negatively associated with firm performance in a cross-sectional study, with relevant moderators.[13] A register-based study using 28 Swedish CEO cohorts found that health predicted CEO appointment, poor health predicted turnover and poorer firm outcomes, and a one-standard-deviation deterioration in mental health was associated with a 6% performance reduction relative to the mean for smaller-firm CEOs.[14] These are unusually direct leader-population findings, but they remain observational and do not validate integrated Biological Capacity as the causal determinant.

Upper Echelons Theory supplies an important organizational bridge by proposing that organizational outcomes partially reflect top managers' characteristics and interpretations.[15] It is a conceptual theory, not evidence that Biological Capacity determines organizational outcomes.

SECTION 10

Experience Capital and performance over time

Experience Capital is accumulated experience, knowledge, understanding, pattern recognition, and expertise that can be applied to judgment and action. BOL distinguishes **accumulated** from **deployable** Experience Capital and examines how Biological Capacity contributes to both.

> Experience Capital is what experience builds; Biological Capacity is what lets a leader use it.

The signature line captures deployment, but the full proposition also includes accumulation. Biological Capacity may influence continued learning, memory, adaptation, practice, and integration of feedback. Opportunity and experience quality remain necessary; Biological Capacity alone does not create Experience Capital.

Performance and other outcomes over time = f(Biological Capacity, Experience Capital, their interaction, and context)

10.1 Accumulated and deployable Experience Capital

Accumulated
Relevant knowledge, patterns, and expertise developed through experience. Indicators include domain knowledge; depth, breadth, relevance, and recency; critical-incident repertoire; pattern recognition; and mental-model quality.

Deployable
The portion that can be accessed, integrated, and applied under current conditions. Indicators include role-specific scenarios; decision quality and calibration; transfer to novelty; prioritization under load; error detection; and degradation and recovery.

Tenure, credentials, and job titles indicate opportunity to acquire experience, not its quality or deployability.

10.2 An interaction, not a literal percentage rule

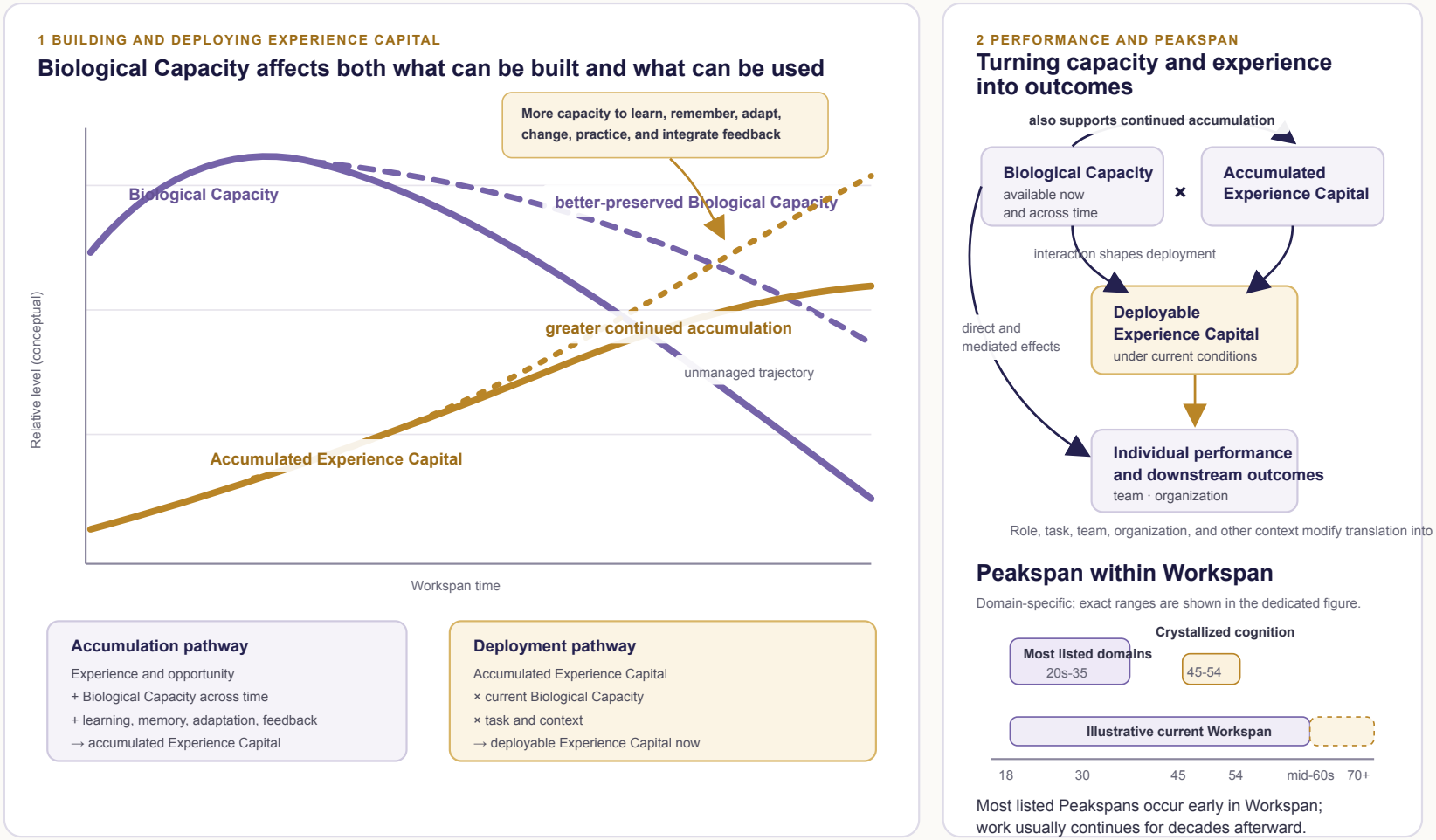
Deployable Experience Capital = f(Biological Capacity × accumulated Experience Capital, context)

The multiplication sign denotes an **interaction hypothesis**, not a rule that 0.7 Biological Capacity yields exactly 70% deployment. A proportional rule would require validated ratio scales, evidence of linearity, domain- and role-specific calibration, and within-person and out-of-sample validation. Compensation may also change the relationship.[17]

Experience Capital remains parallel to Biological Capacity. It is not part of a Biological Capacity score or a fourth capacity dimension.

How Biological Capacity shapes Experience Capital and performance over time

Conceptual relationships and hypotheses - not empirical trajectories, effect sizes, or forecasts



BOL Foundational Model v1.0 | The trajectories are hypotheses for research and communication, not population norms or individual predictions.

Figure 2. Biological Capacity and Experience Capital across Workspan. The visual is conceptual, not an estimated population curve. Experience Capital usually continues accumulating while Biological Capacity changes, but the rate and deployability of that accumulation may be affected by available capacity. A less severe capacity decline is hypothesized to support greater continued accumulation and deployment. The curves do not imply one universal peak age, one aggregate Biological Capacity percentage, or a validated intervention effect.

SECTION 11

Peakspan, Workspan, and life-course context

Peakspan is the time during which a defined function remains at or above 90% of its peak functional performance.[18] It is domain-specific: cardiorespiratory function, musculoskeletal function, fluid cognition, crystallized cognition, sensory function, immune measures, and work performance do not share one curve or one peak age.

Workspan is the period in which a person can participate in meaningful and sustainable work. It begins and ends at different ages across individuals, countries, education paths, occupations, preferences, health conditions, and pension systems. OECD policy data place current normal retirement ages around the mid-60s on average and show higher future ages under current legislation, with several countries reaching 70 or above.[19] These are policy anchors rather than personal Workspan definitions.

Healthspan refers to years lived in health or free from specified disease and disability, depending on the operational definition. A person may remain disease-free while already experiencing meaningful loss in a capacity or function relevant to demanding work. Peakspan therefore asks a different question from Healthspan.

Lifespan is the total duration of life. It has lengthened substantially over time at the population level, but longer Lifespan does not automatically mean proportionately longer Healthspan, Peakspan, or Workspan.[23] BOL therefore treats lifespan extension as life-course context, not as evidence that capacity or sustainable work has extended by the same amount.

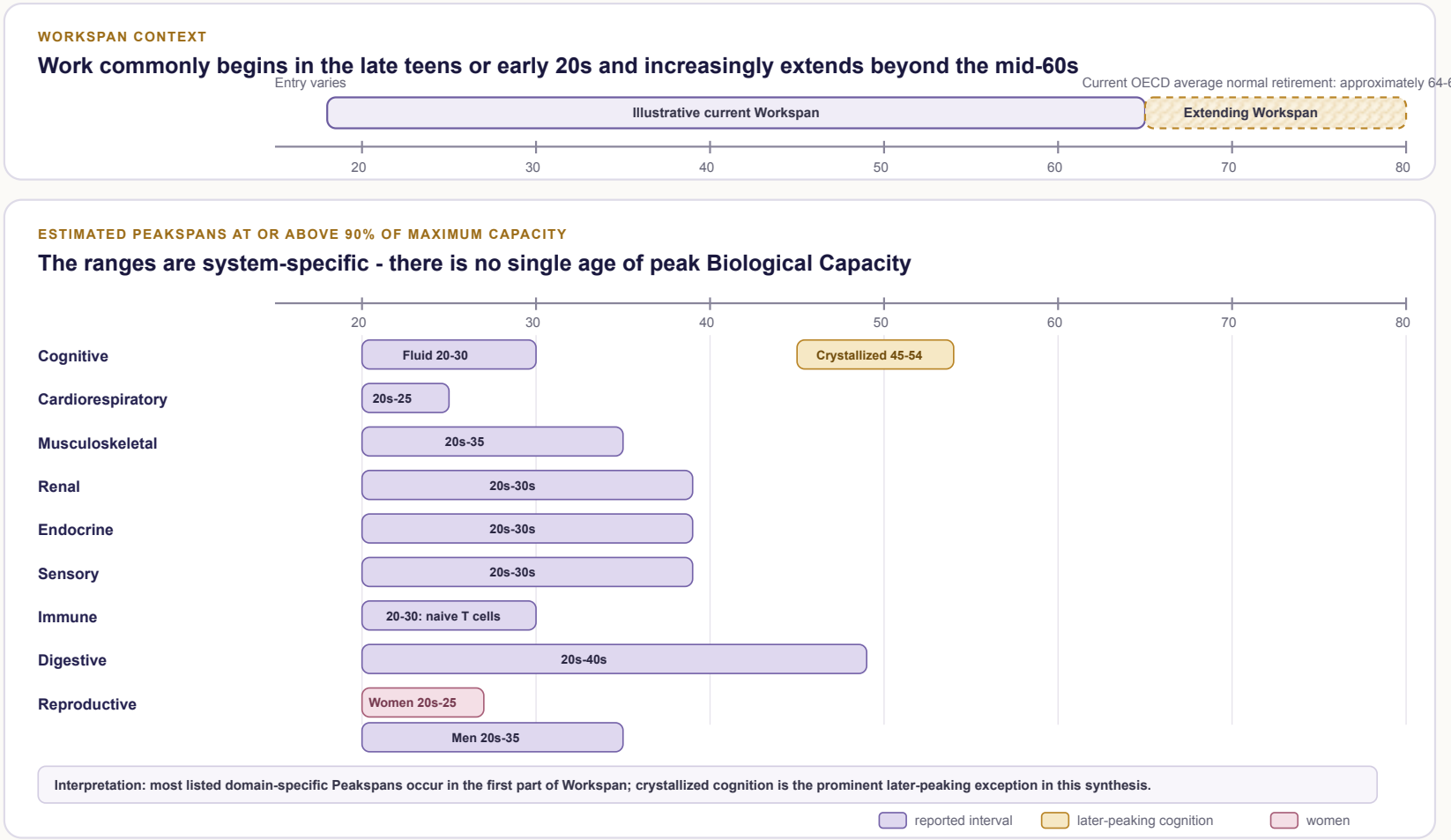
11.1 Illustrative Peakspan intervals

Domain	Estimated interval at or above 90% of peak	Boundary
Fluid cognition	20-30	Different cognitive abilities have asynchronous trajectories.
Crystallized cognition	45-54	Knowledge-based ability does not represent all cognition or all professional expertise.
Cardiorespiratory	20s-25	Training, health, sex, and measurement affect individual trajectories.
Musculoskeletal	20s-35	Strength, power, mass, and function are not interchangeable.
Renal, endocrine, sensory, immune	Largely 20s-30s	Intervals are based on different indicators and cannot be combined as one capacity score.
Digestive	20s-40s	Broad system label with multiple functions.
Reproductive	Women 20s-25; men 20s-35	Reproductive performance is not total Physiological Capacity.

The BOL aim is to preserve and develop Biological Capacity so that people can sustain high-quality performance and continue accumulating and deploying Experience Capital across longer working lives. The claim that a BOL intervention extends Peakspan, Workspan, or Healthspan remains a hypothesis until tested.

Most domain-specific Peakspans occur near the beginning of Workspan

Peakspan is measured separately for each function; Workspan extends for decades beyond many early-adult functional peaks.



Peakspan ranges: Zhavoronkov, Ying & Wilczok (2026), Table 1 and system sections. Estimated literature ranges with substantial individual variation - not personal cutoffs.

Workspan policy anchors: OECD (2025), based on full-career entry at 22. Color distinguishes interval type; written labels carry the meaning.

BOL Foundational Model v1.0 | Workspan is broader than statutory employment and varies by person, occupation, country, health, preference, and opportunity.

Figure 3. Domain-specific Peakspan in relation to Workspan. Literature-derived intervals at or above 90% of maximum differ by domain. Many physiological functions and fluid cognition peak near the beginning of a typical Workspan, while crystallized cognition peaks later. Color distinguishes reported interval types, while the written labels carry the meaning. Age ranges are population-level estimates with substantial individual variation, not deterministic personal deadlines.[18,20]

11.2 Menopause and other life-course transitions

The menopausal transition belongs within Biological & Life-Course Context. It may affect measures across Physiological, Cognitive, and Psychological Capacity, but BOL should not apply one universal decline to total capacity or work performance. A 2025 systematic review found that menopausal status was not consistently related to work ability, while findings for symptom effects were mixed and studies had important limitations.[21] Menopause should therefore be modeled as a time-varying and heterogeneous modifier, with attention to symptoms, timing, work conditions, personal reference ranges, and recovery.

The same principle applies to other life-course events and transitions: recognize their possible importance, measure relevant functions, and avoid stereotypes or fixed penalties.

SECTION 12

Evidence base and claim boundaries

BOL uses four explicit evidence labels. The label belongs to the specific claim, not permanently to a source.

Established external evidence
Supported by the cited source within its actual population, design, endpoint, and limitations.

Evidence-supported BOL interpretation
A transparent synthesis or extension of external evidence into the BOL architecture.

BOL hypothesis
A testable relationship or effect that has not yet been established.

Future research proposition
A measure, instrument, study, or product direction proposed for development.

How the labels are used. In this edition, the written labels appear in callouts and claim-boundary passages throughout the paper. Color is a navigation aid only; the text label and its stated limitation carry the meaning.

12.1 What the current evidence supports

- Capacity can be treated as multidimensional, and environment should remain distinct from personal capacity.[1,2]
- Reserve and recovery are most defensibly assessed through challenge and repeated observation rather than one resting measure.[3,4]
- Short-term sleep loss can impair capacity-relevant cognitive outcomes, including sustained attention after one restricted night.[7,22]
- Leader sleep can affect leadership behavior and follower perception through measured mediators.[11,12]
- Leader burnout and health have observational associations with firm-relevant outcomes in direct CEO samples.[13,14]
- Aging biomarkers and clocks are heterogeneous and do not replace direct functional measurement.[10]
- Functional peaks are asynchronous across systems and cognitive abilities.[18,20]

12.2 What remains a BOL proposition

- the exact three-dimension BOL measurement model in leaders;
- a validated integrated Biological Capacity score;
- the interaction between Biological Capacity and accumulated Experience Capital;

- the proposition that Biological Capacity affects continued Experience Capital accumulation;
- prospective prediction of leadership, team, or organizational KPIs from BOL measures;
- the extension of Peakspan, Workspan, or Healthspan through BOL interventions.

12.3 Deliberate exclusions

CEO hospitalization and executive-death studies are excluded from the active evidence spine because catastrophic events and availability shocks do not measure general Biological Capacity. A CEO marathon working paper is also excluded because marathon completion is a disputed self-selection proxy and the work remains non-peer-reviewed. Consulting and vendor statistics are excluded from the foundational scientific evidence where their sampling and review standards are unclear.

SECTION 13

Implications and research program

13.1 Implications for leadership and organizations

- **Leadership performance is state-dependent as well as skill-dependent.** The same leader may not have the same available capacity across different conditions.
- **Experience is not automatically deployable.** Organizations should distinguish accumulated expertise from the capacity to access and apply it reliably under current demand.
- **Performance sustainability requires more than a high current level.** Reserve and recovery affect how capacity holds under load and returns after it.
- **Intervention should be linked to function and outcomes.** Biomarker improvement without relevant functional or performance improvement is insufficient.
- **Organizational conditions belong inside the analysis.** BOL should not personalize systemic overload or normalize unhealthy work through individual reference ranges.

13.2 Priority validation sequence

1. Establish construct coverage and reliable measures within Cognitive, Psychological, and Physiological Capacity.
2. Define standardized or well-characterized current and reference levels.
3. Develop ethical, domain-appropriate challenge and recovery protocols.
4. Test convergent and discriminant validity against adjacent constructs.
5. Validate proximal, role-specific outcomes before distal team and organizational KPIs.
6. Use repeated within-person studies to test acute state changes and Experience Capital deployment.
7. Use longitudinal studies to test reference level, reserve, recovery, accumulation, and trajectory.
8. Use intervention studies to test whether driver changes improve both capacity measures and relevant outcomes.
9. Validate subgroup performance, fairness, privacy, and unintended effects before organizational implementation.

FALSIFIABLE CORE

BOL becomes scientifically valuable to the extent that it makes better, testable predictions than simpler alternatives. The research program must show when Biological Capacity adds explanatory or predictive value beyond age, health status, personality, experience, job demands, and conventional leadership measures.

13.3 Boundaries for responsible use

Biological and psychological data are sensitive. Future applications should require voluntary and informed participation, data minimization, strict access control, clear separation from punitive performance management or unsupported medical interpretation, subgroup-validity testing, and explicit separation of observed data, inferred state, prediction, and recommendation. No single wearable signal, biological-age clock, or composite score measures the whole person.

SECTION 14

How to cite this paper

O'Donovan, I. (2026). *Bio-Optimized Leadership™: A foundational model of Biological Capacity, leadership performance, and outcomes across longer working lives* (Foundational Whitepaper, Version 1.0). Bio-Optimized Leadership. https://doi.org/10.5281/zenodo.21538567

This paper is the intellectual property of Ines O'Donovan. DOI: 10.5281/zenodo.21538567. The canonical publication record is maintained through Zenodo and at biooptimizedleadership.com.

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