

Dreams on the Neighboring Fiber:

A Topological–Dynamical Framework for
Dream Structure and Generativity

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May 11, 2026

Abstract

Dream phenomenology exhibits a distinctive pattern: dream content resembles waking experience in broad organisational form while differing from it in nearly every concrete particular, and the empirical literature documents this structural deformation extensively without specifying its formal character. This paper proposes a framework, assembled from concepts in theoretical physics and algebraic topology, in which the waking human is modelled as a dynamical system whose typical trajectories are confined to a low-dimensional manifold within a high-dimensional state space. Sleep is modelled as a partial relaxation of the constraints defining this manifold, allowing dream trajectories to wander on a tubular neighborhood—a *neighboring fiber*—that shares topological structure with the waking manifold while differing in geometric realisation.

The framework’s central thesis is a two-fold topological correspondence between dreaming and the waking phase space. *Structurally*, the form of dream content is topologically similar to the form of waking-state trajectories on the waking manifold: dream content preserves topological invariants (connectivity, loops, higher-order relational structure) while releasing geometric specificity (identities, distances, temporal order). *Generatively*, the dynamics producing dream content on the neighboring fiber is topologically similar to the dynamics producing waking experience on the waking manifold: constraint relaxation expands the accessible region without altering the topological character of state-to-state transitions. The phenomenology of “similar yet not” is on this account a structural residue of the first correspondence; the apparent meaningfulness of dream form is a structural residue of the second.

A refinement expressed in persistent-homology language predicts that the probability of a feature appearing in dream content tracks its cross-scale persistence in waking experience. Precognitive-feeling dreams are accounted for through slow-variable sampling on the neighboring fiber: signals accumulated below the threshold of waking attention organise the relaxed exploration, occasionally yielding content whose topological structure matches events later consciously encountered. Four empirical predictions distinguish the framework from competing accounts: asymmetric fidelity between relational and metric attributes; an ordering of preservation by cross-scale persistence; constraint-specific phenotypes under selective neural or pharmacological perturbation; and slow-variable correlates of precognitive-feeling reports.

The paper makes two contributions. First, it proposes a conjectural framework drawing on dynamical systems theory and algebraic topology to describe the relation between waking and dreaming cognition, anchored by a central thesis asserting topological correspondence in both structure and generativity. Second, it uses the framework to derive structural explanations for three distinctive features of dream phenomenology—the simultaneous resemblance and difference between dream content and waking experience, the apparent meaningfulness of dream content, and the occasional appearance of precognitive-feeling dreams—and to extract four empirical predictions that distinguish the framework from competing accounts.

Keywords: dream phenomenology; topological dynamics; persistent homology; cognitive manifold; constraint relaxation.

1 Introduction

Dream reports gathered systematically over more than a century exhibit a distinctive pattern: their content resembles waking experience in broad organisational form—there are agents, settings, events, a sense of unfolding sequence—while differing from it in nearly every concrete particular. Identities are unstable, settings combine features of multiple remembered places, temporal sequence is locally coherent but globally violable, causal links are felt rather than seen. Despite these systematic divergences, dreams are rarely reported as random. The explanatory challenge they pose is to account for this pattern: dreams exhibit a specific kind of structured deformation, preserving something while releasing something else.

Existing accounts (reviewed in §2.1–§2.2)—neurophysiological, computational, psychoanalytic, cognitive-psychological, philosophical—illuminate the substrate of dream generation and characterise its phenomenology, while leaving an explanatory gap in one specific respect: the form of the transformation that takes waking material to dream content. Across the traditions, the transformation is named (“condensation,” “synthesis,” “elaboration,” “regularisation,” “hallucination”) without being specified in a manner that generates structural predictions.

This paper proposes a framework, assembled from concepts in theoretical physics and algebraic topology (introduced in §2.3), that addresses this gap. The framework’s central conjecture is that dreaming is constrained exploration on a *neighboring fiber* of the waking cognitive manifold: a tubular neighborhood, obtained by relaxing a subset of the constraints that define the waking manifold, on which trajectories preserve topological structure (connectivity, loops, higher-order relational features) while releasing geometric specificity (identities, distances, temporal ordering). The phenomenology of “similar yet not” is on this account a structural residue of the topology that the neighboring fiber inherits from the waking manifold. A refinement expressed in persistent-homology language predicts that the probability of a feature appearing in dream content tracks its cross-scale persistence in waking experience. Precognitive-feeling dreams are addressed through slow-variable sampling: signals accumulated below the threshold of waking attention organise the relaxed exploration of the oneiric fiber, occasionally yielding content whose topological structure matches events later consciously encountered.

The paper makes two contributions. First, it proposes a conjectural framework drawing on dynamical systems theory and algebraic topology to describe the relation between waking and dreaming cognition. Second, it uses the framework to derive structural explanations for three distinctive features of dream phenomenology—the simultaneous resemblance and difference between dream content and waking experience, the apparent meaningfulness of dream content, and the occasional appearance of precognitive-feeling dreams—and to extract four empirical predictions that distinguish the framework from competing accounts.

The framework is conjectural in a precise sense: its central claims await both fuller mathematical formalisation and empirical test, and each claim is marked with the appropriate epistemic environment (*speculation* for picture-level proposals, *conjecture* for refined and risky claims, *prediction* for what follows from the framework if it holds). The conjectural label indicates that the claims invite test, and it earns the paper the right to state them sharply. The framework is offered as a substantive position on how dreams are structured.

The remainder of the paper is organised as follows. §2 surveys related work and supplies brief definitions of the technical concepts employed. §3 develops the framework. §4–§5 state the central conjecture and its refinement. §6 addresses precognitive-feeling dreams. §7 draws out four empirical predictions. §8 locates the framework relative to existing accounts. §9 lists open problems. §10 concludes.

95 2 Background

96 2.1 The Structure of Dreams

97 Empirical and conceptual work on the structure of dreams aims to characterise what dream
98 content looks like, abstracted from its causal substrate. The tradition spans content-analytic
99 quantification, philosophical phenomenology, and the cataloguing of features that distinguish
100 dream content from waking experience.

101 **Content-analytic quantification.** Hall and Van de Castle [21] established the foundational
102 coding scheme for dream content: characters classified by sex, age, familiarity, and relation
103 to the dreamer; settings by indoor/outdoor and familiarity; activities, interactions (aggressive,
104 friendly, sexual), emotions, success/failure, fortune/misfortune. The HVDC system has sup-
105 ported decades of comparative work documenting cross-cultural and individual regularities in
106 dream content. Domhoff [10, 11] extended this tradition with normative databases, statistical
107 methods, and the *continuity hypothesis*: the proposition that dream content statistically reflects
108 waking concerns, in the sense that what occupies a person’s waking thought is over-represented
109 in their dreams. The continuity hypothesis has substantial empirical support and now serves
110 as a baseline against which discontinuities are catalogued.

111 **Bizarreness and incongruity.** A distinct line of work has measured precisely the ways in
112 which dream content departs from waking experience. Hobson and colleagues [25] developed
113 scales for rating bizarreness along three dimensions—incongruity (impossible combinations),
114 discontinuity (unprepared transitions), and uncertainty (vagueness or ambiguity)—and showed
115 that dream reports score significantly higher on all three than waking-thought reports gathered
116 under matched conditions. Revonsuo and Salmivalli [41] refined the methodology and demon-
117 strated that bizarreness is structured rather than random: certain features (character identity,
118 spatial setting) are bizarre more often than others (linguistic content, basic body schema). These
119 findings establish that dreams are not generically distorted but distorted in specific structural
120 patterns—a fact any structural theory must accommodate.

121 **Identity, character, and setting structure.** Several robust patterns emerge from content-
122 analytic work. Characters frequently exhibit *identity bivalence*: a dreamed character is “known
123 to be” one person while resembling another, or two simultaneously. Settings exhibit *composi-*
124 *tional fusion*: dreamed locations combine features of multiple remembered places. Temporal
125 sequence is locally coherent but globally violable, with scene transitions occurring without con-
126 tinuous spatial trajectory. These features cluster, suggesting they reflect a unified structural
127 property rather than independent quirks. Strauch and Meier [53] provide systematic documen-
128 tation of such features across thousands of laboratory-collected dream reports.

129 **Narrative and discourse structure.** Foulkes [16, 17] demonstrated through systematic de-
130 velopmental study that dream content acquires narrative coherence gradually across childhood,
131 paralleling the development of waking cognitive capacities for narrative construction. Pre-verbal
132 and early-childhood dreams lack the complex narrative arc typical of adult dreams. States
133 [49, 50] analysed dream reports as narrative texts, identifying discourse-level structures (orien-
134 tation, complication, resolution) common to dreams and waking narrative. This work suggests
135 that dream content is organised at a discourse level, not merely an associative one—a point
136 underscored by Kahn et al. [32], who showed that dream reports exhibit higher-order coher-
137 ence properties (theme persistence, character reidentification) measurable through quantitative
138 discourse analysis.

139 Contextualising images and emotional structure. Hartmann [22, 23] proposed that cen-
140 tral dream images function as visual metaphors for the dreamer’s dominant emotional concerns—
141 a tidal wave for overwhelming anxiety, a hunted figure for vulnerability. The hypothesis posits
142 a structural mapping from emotional state to visual content via metaphor, and is supported
143 by content analysis of dreams reported during periods of significant emotional disturbance (be-
144 reavement, trauma, illness). Related work on the emotional structure of dreams [44, 38] has
145 established that emotional content is non-randomly distributed across dream reports, that neg-
146 ative emotions are more frequent than positive ones, and that emotional intensity correlates
147 with bizarreness measures.

148 Phenomenological and philosophical structure. Windt’s [58, 59] extended treatment
149 characterises the structural features of dream experience under the heading of *immersive spa-*
150 *tiotemporal hallucination*: dreams place a first-person experiential subject in a spatiotempo-
151 ral scene that is hallucinated rather than perceived, with characteristic structural properties
152 (self-localisation, temporal flow, perspectival situatedness) shared with waking experience but
153 realised without external sensory input. Metzinger’s [39] self-model theory analyses how the
154 dreaming self is constructed as a transparent phenomenal representation, with characteristic
155 distortions of self-modelling explaining several otherwise puzzling features of dream experience.
156 These accounts contribute structural characterisations that complement empirical content anal-
157 ysis at the level of phenomenal organisation.

158 Lucid dreams as a structural probe. Lucid dreaming—dreaming with concurrent aware-
159 ness of dreaming—has been used to probe dream structure under conditions of metacognitive
160 access. LaBerge [33, 34] established methods for verifying lucidity within REM sleep through
161 pre-arranged eye-movement signals. Voss and colleagues [55, 56] have linked lucid states to
162 elevated frontal gamma activity, and have shown that transcranial stimulation in the gamma
163 band can induce lucidity. Lucid-dream studies confirm that core structural features (spatial sit-
164 uatedness, narrative coherence, characterological stability) persist under metacognitive scrutiny,
165 supporting the view that dream structure is generated during sleep rather than constructed at
166 recall.

167 Cross-cultural and developmental variation. Comparative work [2, 43] has documented
168 both invariants and culturally specific variation in dream content. Some structural features
169 (presence of characters, spatial settings, emotional valence, narrative form) appear universal
170 across cultures; others (specific motifs, frequency of dream recall, attribution of significance
171 to dreams, presence of religious content) vary substantially. The combination of universal
172 structure and culturally modulated content is a constraint on any unified account of dream
173 form: the universal features must be explicable by mechanisms shared across humans, while
174 culture-specific features must enter at a stage open to social and linguistic shaping.

175 Summary. The body of work surveyed under this heading establishes that dream content has
176 *specific, measurable structural features*: bivalent identities, fused settings, locally coherent nar-
177 rative, metaphorically loaded emotional imagery, and characteristic distributions of bizarreness
178 across content categories. Table 1 summarises the surveyed contributions. The question of why
179 these features take the form they do—rather than some other—requires an account of dream
180 generation.

Table 1: Summary of literature on the structure of dreams.

Reference	Tradition / method	Key structural claim
Hall & Van de Castle [21]	Content analysis	HVDC coding system covering characters, settings, interactions, emotions, success/failure, fortune/misfortune
Domhoff [10, 11]	Quantitative content analysis	Continuity hypothesis: dream content statistically reflects waking concerns
Hobson et al. [25]	Bizarreness measurement	Three-dimensional bizarreness scale (incongruity, discontinuity, uncertainty); dream reports score higher than matched waking reports
Revonsuo & Salmivalli [41]	Bizarreness analysis	Bizarreness is feature-specific and non-random across content categories
Strauch & Meier [53]	Experimental laboratory	Documentation of identity bivalence, setting fusion, scene transitions across thousands of laboratory reports
Foulkes [16, 17]	Developmental cognitive psychology	Narrative coherence of dreams develops gradually with cognitive maturation
States [49, 50]	Literary / narrative analysis	Dreams exhibit discourse-level structure (orientation, complication, resolution) common to waking narrative
Kahn, Pace-Schott & Hobson [32]	Quantitative discourse analysis	Higher-order coherence in dreams: theme persistence and character reidentification
Hartmann [22, 23]	Phenomenological-clinical	Central dream images function as visual metaphors for dominant emotional concerns
Schredl & Doll [44]	Content analysis (emotion)	Emotional content non-randomly distributed; negative valence overrepresented
Malinowski & Horton [38]	Memory source analysis	Dream content sources autobiographical rather than episodic memory traces
Malcolm [37]; Dennett [8]	Philosophy of mind	Skepticism about dreams as in-sleep experiences; cassette theory permitting alternative relations of dream-as-experience to dream-as-report
Windt [58, 59]	Philosophy / phenomenology	Immersive spatiotemporal hallucination model: dreams as hallucinated first-person scenes with characteristic structural properties
Metzinger [39]	Philosophy of mind	Self-model theory: dreaming self as transparent phenomenal representation with characteristic distortions
LaBerge [33, 34]	Lucid dream research	Methodology for verifying lucidity within REM via pre-arranged eye-movement signals
Voss et al. [55, 56]	Lucid dream neuroscience	Lucid states correlate with elevated frontal gamma activity; inducible via transcranial stimulation
Schredl [43]	Survey methodology	Dream recall frequency as central measurement variable across studies
Bulkeley [2]	Comparative cultural / religious	Cross-cultural variation in dream content alongside universal structural features

181 2.2 The Generation of Dreams

182 A distinct family of work addresses how dreams are produced: by what neural, computational,
183 or functional process the structural features documented in the previous subsection arise. The
184 accounts here are not mutually exclusive; each illuminates different aspects of generation.

185 **The neurophysiological lineage.** Modern study of dream generation begins with Aserin-
186 sky and Kleitman’s [1] discovery of REM sleep and Dement and Kleitman’s [7] demonstration
187 that REM correlates with vivid dream reports. The activation–synthesis hypothesis of Hobson
188 and McCarley [24] proposed that REM dreams are the cortex’s synthesis of stochastic activa-
189 tion arriving from brainstem cholinergic systems via pontine–geniculate–occipital (PGO) waves;
190 bizarreness, on this view, reflects the cortex’s effort to construct narrative from random inputs.

191 The AIM model [26] refined this by indexing conscious state to three neuromodulatory dimen-
192 sions (Activation level, Input source, Modulation by aminergic–cholinergic balance), allowing
193 comparative analysis across waking, NREM, REM, and altered states.

194 **Lesion studies and the forebrain account.** Solms [46, 47] challenged the REM-centred
195 picture through systematic study of brain-lesioned patients: lesions to ventromesial prefrontal
196 white matter and inferior parietal cortex abolish dreaming despite preserved REM, while lesions
197 abolishing REM (e.g., pontine) do not necessarily abolish dreaming. The forebrain account thus
198 locates dream generation in mesocortical and mesolimbic dopaminergic systems associated with
199 motivation and reward, rather than exclusively in brainstem activation. The integration of
200 forebrain and brainstem accounts [27] remains an active area of debate.

201 **Modern neural correlates of dreaming.** Recent neuroimaging has refined the neural pic-
202 ture along several dimensions. Siclari and colleagues [45] used high-density EEG to identify a
203 posterior cortical “hot zone” (parieto-occipital) whose local high-frequency activity correlates
204 with dream report independently of REM/NREM stage—supporting a content-specific, rather
205 than state-specific, neural correlate of dream experience. Horikawa et al. [30] demonstrated,
206 using fMRI and machine-learning decoders, that visual content of dreams can be partially
207 read out from higher visual area activity during sleep, establishing the empirical tractability of
208 dream content’s neural representation. Default-mode network activity in REM sleep [18, 12]
209 has been linked to the self-referential and narrative character of dreams, and Christoff et al. [5]
210 have proposed that dreams represent one extreme of a broader continuum of constrained-to-
211 unconstrained mental activity that also includes mind-wandering.

212 **Memory consolidation and replay.** A parallel tradition treats dreams as the phenomenal
213 correlate of sleep-dependent memory consolidation. Wilson and McNaughton [57] demonstrated
214 reactivation of hippocampal place-cell sequences during subsequent slow-wave sleep, establishing
215 the empirical reality of replay. Stickgold [52], Diekelmann and Born [9], and Pace-Schott [40] syn-
216 thesised the evidence linking sleep-stage architecture to specific consolidation processes: declar-
217 ative memory in slow-wave sleep, procedural and emotional in REM. Stickgold and colleagues
218 [51] proposed that dreams reflect hyperassociative processing during sleep—weakly related mem-
219 ory traces being linked together—possibly explaining the bizarre combinations characteristic of
220 dream content. Whether replay generates the experienced content, or merely co-occurs with
221 independently generated content, remains contested; the evidence supports a strong correlation
222 between sleep-stage memory processes and dream content without establishing direct generative
223 causation.

224 **Computational and predictive-processing accounts.** Crick and Mitchison [6] proposed
225 an early computational theory: dreams as a process of “reverse learning” in which the cortex
226 unlearns spurious associations during REM, with dream content as a side-effect of this unlearn-
227 ing. The hypothesis remained influential as a paradigm even as its specific mechanism faced
228 empirical challenges. Hobson and Friston [28] situated dreaming within the free-energy principle
229 [20], treating dreams as offline operations of the same generative model that supports waking
230 perception, with sensory precision down-weighted during sleep so that prior beliefs dominate
231 the generative process. Hoel [29] proposed the overfitted-brain hypothesis: dreams function
232 as adversarial training data preventing the cognitive system from overfitting to recent waking
233 experience, with the noise and distortion of dream content reflecting this regularisation role.
234 Llewellyn [35, 36] developed the elaborative-encoding account: dreams as the cognitive sys-
235 tem’s reinstatement of waking experience through associative elaboration, drawing parallels to
236 the method of loci in classical mnemonics. These computational accounts share an explanatory
237 virtue (quantitative anchoring) and a limitation (generic structural predictions).

238 Functional and evolutionary accounts. Revonsuo [42] proposed that dreams are a virtual
239 rehearsal of evolutionarily relevant threat scenarios, with the bizarre and emotionally intense
240 character of dreams reflecting selection for threat-simulation efficacy. The threat-simulation
241 theory has been extended to social simulation by Revonsuo, Tuominen, and Valli [54]: dreams
242 as rehearsal of social interaction patterns. Cartwright [4] proposed a mood-regulatory function:
243 dreams as integration of emotionally significant waking material, supported by studies of dream
244 content in subjects undergoing major life stressors (divorce, bereavement). These functional
245 accounts make structural predictions (overrepresentation of threats, of social interactions, of
246 emotionally salient content) that have been partially confirmed in content analyses.

247 Psychoanalytic generation. Freud’s [19] account of dream generation proposed the *dream-*
248 *work*: a set of transformations—condensation, displacement, considerations of representability,
249 and secondary revision—operating on latent dream-thoughts to produce manifest dream content,
250 with the function of disguised wish-fulfillment. The specified mechanisms (combining multiple
251 referents into one image; substituting one element for another; translating thoughts into visual
252 scenes; imposing post-hoc narrative coherence) constitute a specific theory of *how dream con-*
253 *tent is generated* from waking material. Jung’s [31] elaboration added archetypal contents and a
254 compensatory function in which dreams supplement what is one-sided or unconscious in waking
255 life. Whatever the metaphysical commitments, the psychoanalytic tradition was the first to
256 propose specific generative transformations rather than mere associative production. Contem-
257 porary neuropsychanalysis [48] has sought to ground these mechanisms in mesocortical reward
258 circuitry, treating dream content as expressing motivational salience structures active during
259 sleep.

260 Cognitive-psychological generation. The cognitive-psychological tradition replaced un-
261 conscious symbolism with shared cognitive substrate. Foulkes [16, 17] treated dream generation
262 as continuous with waking cognitive processes operating offline, supported by developmental
263 data showing that dream complexity tracks general cognitive maturation. Domhoff [11, 12, 13]
264 developed the *neurocognitive theory of dreaming*: dreams are generated by the same default-
265 mode network and conceptual-schematic systems that produce waking mind-wandering, with
266 the specific structural features of dreams arising from the disconnection of these systems from
267 external input and executive control during sleep. The theory accommodates a broad range
268 of empirical findings—continuity of content with waking concerns, developmental trajectory,
269 default-network correlates, similarity to mind-wandering—and has emerged as a leading con-
270 temporary synthesis.

271 The status of generation accounts. The accounts surveyed under this heading illuminate
272 the neural, computational, and functional substrate of dream generation, summarised in Table 2.
273 They specify, with varying degrees of precision, what the brain does during sleep that produces
274 dream content. What they specify less directly is the form of the mapping from waking ma-
275 terial to dream content: *why condensation produces these condensations and not others; why*
276 *bizarreness takes these specific structural forms rather than others; why dreams resemble waking*
277 *experience in topological organisation while differing in geometric particulars.* The framework de-
278 veloped below addresses this remaining structural question—taking the empirically established
279 generation mechanisms as compatible substrate, and asking what mathematical structure char-
280 acterises the transformation those mechanisms effect.

Table 2: Summary of literature on the generation of dreams.

Reference	Tradition / approach	Mechanism or claim proposed
Aserinsky & Kleitman [1]	EEG psychophysiology	Discovery of REM as a distinct sleep stage with eye-movement and EEG signatures
Dement & Kleitman [7]	Psychophysiology	REM correlates with vivid dream reports on awakening
Hobson & McCarley [24]	Neurophysiology	Activation-synthesis: cortical synthesis of stochastic brainstem activation via PGO waves
Hobson, Pace-Schott & Stickgold [26]	Cognitive neuroscience	AIM model: conscious state indexed to Activation, Input source, Modulation (aminergic/cholinergic balance)
Hobson [27]	Neurophysiology	REM dreaming as protoconsciousness; integration of brainstem and forebrain accounts
Solms [46, 47]	Lesion neurology	Forebrain account: dopaminergic mesocortical/mesolimbic systems generate dream content; dreaming dissociable from REM
Solms & Turnbull [48]	Neuropsychanalysis	Motivational salience structures active during sleep express in dream content
Siclari et al. [45]	High-density EEG	Posterior cortical “hot zone” high-frequency activity correlates with dream report across REM and NREM
Horikawa et al. [30]	fMRI machine-learning decoding	Visual content of dreams partially readable from higher visual area activity during sleep
Domhoff [12]; Fox et al. [18]; Christoff et al. [5]	Default-mode network neuroscience	DMN as substrate for dreaming and mind-wandering; dreams as one extreme of a constrained-to-unconstrained continuum
Wilson & McNaughton [57]	Single-unit recording	Hippocampal place-cell sequence replay during slow-wave sleep
Stickgold [52]; Diekelmann & Born [9]	Sleep neuroscience	Sleep-stage-specific memory consolidation (declarative in SWS, procedural/emotional in REM)
Stickgold et al. [51]	Sleep neuroscience	Hyperassociative offline reprocessing during sleep; weakly related traces linked
Pace-Schott [40]	Cognitive neuroscience	Frontal lobe contribution to dream generation and recall
Crick & Mitchison [6]	Computational / theoretical	Reverse learning: cortex unlearns spurious associations during REM
Hobson & Friston [28]; Friston [20]	Free-energy principle	Dreams as offline generative model with reduced sensory precision; priors dominate
Hoel [29]	Machine-learning analogy	Overfitted-brain hypothesis: dreams as adversarial training data preventing overfitting to waking input
Llewellyn [35, 36]	Memory psychology	Elaborative encoding; dreams as a method-of-loci analogue supporting semantic memory
Revonsuo [42]	Evolutionary psychology	Threat-simulation theory: dreams as virtual rehearsal of evolutionarily relevant scenarios
Tuominen et al. [54]	Evolutionary psychology	Social-simulation theory: dreams as rehearsal of social interaction patterns
Cartwright [4]	Clinical psychology	Mood regulation via integration of emotionally significant waking material
Freud [19]	Psychoanalysis	Dreamwork: condensation, displacement, considerations of representability, secondary revision; disguised wish-fulfillment
Jung [31]	Analytical psychology	Compensation: dreams supplement what is one-sided in waking life; archetypal contents
Foulkes [16, 17]	Cognitive psychology	Dream generation continuous with waking cognition operating offline

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Table 2 (continued)

Reference	Tradition / approach	Mechanism or claim proposed
Domhoff [11, 13]	Neurocognitive theory	DMN and conceptual-schematic systems generate dream content; structural features arise from sleep-state disconnection from input and executive control

2.3 Mathematical Preliminaries

The framework draws on tools from theoretical physics and algebraic topology. We supply working definitions of the concepts figuring in the argument; full treatments are available in the cited references.

Dynamical systems, state spaces, and manifolds. A *dynamical system* on a state space $\mathcal{X}$ is specified by an evolution rule $\dot{x} = f(x; u)$ describing how the state $x \in \mathcal{X}$ changes in time under inputs u . A *manifold* is a space that locally resembles Euclidean space; a d -dimensional manifold $\mathcal{M}$ embedded in a higher-dimensional ambient space $\mathcal{X}$ is a d -dimensional surface within it. The waking cognitive system is here modelled as a high-dimensional dynamical system whose typical trajectories are confined to a low-dimensional submanifold.

Constraints, constraint relaxation, and tubular neighborhoods. A *constraint* on $\mathcal{X}$ is an algebraic, dynamical, or statistical condition excluding regions of the state space from typical occupation. *Constraint relaxation* is the partial or selective removal of such constraints; trajectories then become accessible to a larger region, typically a *tubular neighborhood* of the original manifold (a thickening obtained by allowing small displacements normal to the manifold). The framework borrows “fiber” as the descriptor for this neighborhood, reflecting its origin in fiber-bundle geometry, where a fiber is the local structure orthogonal to a base manifold.

Slow–fast decomposition and slow variables. Many physical systems exhibit separation of timescales: some variables evolve fast (relaxation, oscillation), others slow (drift, accumulation). *Slow–fast decomposition*, formalised in Fenichel theory [15], treats fast variables as adiabatically slaved to slow ones, with the system’s effective dynamics determined by the slow variables alone over long times. *Slow variables*, in the present paper, include weak somatic signals, environmental regularities, and social cues whose accumulation rate is below the bandwidth of conscious access during waking life.

Topology, topological invariants, and homotopy. *Topology* studies properties of spaces preserved under continuous deformation (stretching, bending, twisting, excluding tearing or gluing). *Topological invariants* are properties unchanged by such deformations: examples include the number of connected components, the number and dimension of holes, and higher-order homological structure. Two spaces related by a continuous deformation that admits continuous inverse—a *homotopy equivalence*—share all topological invariants while potentially differing in every geometric particular (size, shape, distance).

Persistent homology and cross-scale persistence. *Persistent homology* [3, 14] is a technique from topological data analysis that tracks how topological features (connected components, loops, higher-dimensional holes) appear and disappear as one filters a space across a scale parameter. A feature’s *persistence* is the range of scales over which it exists; long-persistence features are robust to scale variation, short-persistence features are scale-fragile. The framework’s refined conjecture is expressed in this language.

318 3 The Framework

319 3.1 Why Dynamical Systems and Algebraic Topology

320 Before stating the framework’s definitions and central thesis, we make explicit the method-
321 ological choice that underlies them: the decision to model the dreaming–waking relation using
322 vocabulary from dynamical-systems theory and algebraic topology rather than the symbolic,
323 neuroanatomical, or functional vocabularies dominant in the literature reviewed in §2. Three
324 considerations motivate this choice.

325 **Substrate match.** The cognitive system is a dynamical system. Neural activity is high-
326 dimensional state evolving in time under both internal dynamics (recurrent connectivity, neu-
327 romodulatory modulation, synaptic plasticity) and external forcing (sensory input, embodied
328 action), organised by attractor-like configurations under stable conditions and exhibiting char-
329 acteristic transients under perturbation. This is a description of biological fact, not a metaphor.
330 Dynamical-systems language is therefore native to the substrate the framework addresses; us-
331 ing it does not import a foreign vocabulary but employs the proper one. The recent literature
332 on neural manifolds [5, 18] confirms that the low-dimensional manifold structure presupposed
333 by the framework is empirically tractable in cortical population dynamics, not a theoretical
334 construct.

335 **Phenomenology match.** The phenomenon to be explained is, at its core, a topological phe-
336 nomenon. The literature surveyed in §2.1 documents a specific kind of structured deformation:
337 *relations* between elements of dream content (containment, hierarchy, role, sequence) are pre-
338 served with high fidelity to waking experience, while *geometric particulars* (identity, distance,
339 duration, scale) vary freely. Distinguishing what is preserved under continuous deformation
340 from what is not is the defining concern of topology; persistent homology supplies precise ma-
341 chinery for tracking this distinction across scales. Using topology and dynamical systems to
342 characterise the dream-content–waking-content relation matches the mathematical machinery
343 to the phenomenology rather than imposing a foreign vocabulary on it. The match is sufficiently
344 close that one may suspect the choice of vocabulary is not optional: the structural-deformation
345 phenomenon may admit no compact characterisation outside topology-flavoured mathematics.

346 **Methodological gain.** The vocabulary admits falsifiable predictions. The accounts sur-
347 veyed in §2.2 characterise the dream-content–waking-content relation with informal terms—
348 “condensation,” “displacement,” “synthesis,” “elaboration,” “regularisation,” “hallucination”—
349 that name the phenomenon without specifying it. Such terms are difficult to falsify because they
350 admit any sufficiently distorted content as confirmation. Topological invariants, by contrast,
351 are mathematically defined objects with calculable values; persistence bars are computable;
352 constraint relaxation has specific dynamical signatures. The framework can fail in specific,
353 measurable ways enumerated in §8. This is the difference between a metaphor and a model.

354 3.2 Definitions and Central Thesis

355 With this methodological rationale in place, we state the framework’s two working definitions
356 and central thesis.

357 **Working Definition 1** (Waking manifold). Let the cognitive system occupy states in a high-
358 dimensional space $\mathcal{X}$. Waking life—sensorimotor coupling, real-time prediction, homeostatic
359 regulation, embodied consistency—imposes constraints that confine typical trajectories to a low-
360 dimensional submanifold $\mathcal{M}_{\text{wake}} \subset \mathcal{X}$. The biological correlates of $\mathcal{M}_{\text{wake}}$ are an open question;
361 for the framework’s purposes, $\mathcal{M}_{\text{wake}}$ is the dynamical object on which waking cognition takes
362 place.

Working Definition 2 (Oneiric fiber). During sleep, a subset of the constraints defining $\mathcal{M}_{\text{wake}}$ are relaxed: sensorimotor coupling weakens, and certain consistency checks (logical, identitarian, temporal) cease to bind. The accessible region thickens into a tubular neighborhood $\mathcal{F} \supset \mathcal{M}_{\text{wake}}$, which we call the *oneiric fiber*. Dream trajectories occupy $\mathcal{F}$.

These are working definitions sufficient for the framework. The identification of the constraint set Φ that picks out $\mathcal{M}_{\text{wake}}$, and of the subset Φ' relaxed in sleep, is the principal empirical question the framework opens; we address it in §10.

The framework’s substantive content is the following claim about how the dreaming and waking systems are related.

Central Thesis 1 (Topological dual correspondence). The relation between dreaming and waking cognition is governed by a topological correspondence operating along two parallel axes.

(i) Structural correspondence. The phenomenal and representational *structure* of dream content is topologically similar to the structure of waking-state trajectories on $\mathcal{M}_{\text{wake}}$. Dream content preserves topological invariants of waking experience—connectivity, loops, higher-order relational structure—while geometric attributes—specific identities, metric distances, sequential order—deform freely under the local diffeomorphism class of $\mathcal{F}$.

(ii) Generative correspondence. The *generative dynamics* producing dream content on $\mathcal{F}$ is topologically similar to the generative dynamics producing waking experience on $\mathcal{M}_{\text{wake}}$. Constraint relaxation expands the accessible region without altering the topological character of state-to-state transitions, so that the transformation taking waking experience to dream content is a continuous deformation of generative process rather than a categorical substitution of mechanism.

The two clauses of Thesis 1 address, respectively, the two literatures surveyed in §2. Clause (i) engages the structure of dreams (§2.1, Table 1): it supplies the formal character of the structural deformation that content-analytic and phenomenological work has documented without specifying. Clause (ii) engages the generation of dreams (§2.2, Table 2): it supplies the formal character of the transformation that mechanistic and computational accounts name (“condensation,” “synthesis,” “elaboration,” “regularisation”) without further specification.

The thesis is not derived from the definitions; it is a substantive empirical conjecture about the relation between the dynamical objects the definitions name. The remainder of the paper develops the thesis: §4 unpacks clause (i) as the topological-residue speculation; §5 refines clause (i) into a persistence-graded conjecture; §6 develops clause (ii) as the slow-variable speculation about generative correspondence; §7 applies these to four representative case studies drawn from the structure literature; §8 extracts four empirical predictions that distinguish the framework from competing accounts.

4 The Central Conjecture

Clause (i) of Thesis 1 admits a specific elaboration drawing out its phenomenological consequence.

Speculation 1 (Topological residue). Because dream trajectories wander on a neighborhood $\mathcal{F}$ of $\mathcal{M}_{\text{wake}}$, dream content preserves topological features of waking experience—connectivity, loops, higher-order relational structure—while geometric features—specific identities, metric distances, sequential order—deform freely. The phenomenology of “similar yet not” that the structure literature (§2.1) documents is, on this view, a structural residue of the topology $\mathcal{F}$ inherits from $\mathcal{M}_{\text{wake}}$, neither symbolic nor random.

407 The speculation supplies a unified reading of several otherwise puzzling features of dream
408 reports catalogued by bizarreness measurement [25, 41], identity-bivalence findings [53], and
409 content-fusion analyses. Specific cases—identity bivalence, setting fusion, temporal incoherence—
410 are developed in §7.

411 *Remark 1* (The permissiveness risk). A topological account is permissive: almost any pair
412 of dissimilar phenomena admits *some* continuous deformation between them. Speculation 1
413 alone is insufficient. The refinement in the next section supplies the constraint that makes the
414 framework risky.

415 5 A Refined Conjecture

416 **Conjecture 1** (Persistence-graded preservation). The probability that a feature of waking
417 experience appears in dream content tracks the *persistence* of that feature across cognitive
418 scales: features that remain salient under coarse-graining—features with long persistence bars,
419 in the sense of persistent homology—are preserved with high probability, while features visible
420 only at fine scales are stochastically resampled. The framework predicts not merely *that* dreams
421 preserve structure but *which* structure they preserve.

422 The conjecture is risky and accordingly useful. It is disconfirmed if dream content shows no
423 correlation with cross-scale persistence of waking features, or correlates only with non-structural
424 variables (recency, valence) once persistence is controlled.

425 6 The Generative Speculation

426 Clause (ii) of Thesis 1 concerns generative correspondence: if the dynamics producing dream
427 content on $\mathcal{F}$ is topologically similar to the dynamics producing waking experience on $\mathcal{M}_{\text{wake}}$,
428 then the difference between dream-state and waking-state generativity lies in which variables
429 the relaxed dynamics is able to sample. The slow-fast decomposition introduced in §2.3 supplies
430 a specific answer.

431 **Speculation 2** (Slow-variable access). The cognitive system accumulates slow variables—
432 weak somatic signals, statistical regularities in environment, social cues below the threshold
433 of attention—whose conscious access during waking life is throttled by the bandwidth demands
434 of real-time control. Relaxed exploration on $\mathcal{F}$, freed from these demands, samples regions of
435 state space organised by such slow variables, generating dream content whose topological struc-
436 ture reflects these slow variables rather than the fast variables typically accessible to waking
437 consciousness.

438 Speculation 2 is a specific instance of clause (ii). The topological character of state-to-state
439 transitions on $\mathcal{F}$ is preserved under constraint relaxation; what changes is the set of variables
440 along which transitions are organised. The variables shift from fast (real-time prediction error,
441 sensory drive, action selection) to slow (interoceptive accumulation, environmental regularity,
442 accumulated social-cue patterns). The shift requires no new generative mechanism; it follows
443 from the relaxation of bandwidth-allocation constraints. The empirical consequences of this
444 shift are developed for a specific phenomenon in §7.4.

445 7 Case Studies

446 The framework yields specific readings of distinctive features of dream phenomenology docu-
447 mented in the structure literature (§2.1, Table 1). We work through four representative cases.
448 The first three apply Speculation 1 (and its refinement, Conjecture 1) to clause-(i) phenomena:

identity bivalence, setting fusion, temporal incoherence. The fourth applies Speculation 2 to a clause-(ii) phenomenon: precognitive-feeling dreams.

7.1 Identity Bivalence

Content analysis [21, 53] consistently documents that dream characters frequently exhibit *identity bivalence*: a dreamed person is “known to be” one individual while resembling another, or is simultaneously two people. The phenomenon admits no clean reading on substitution-based accounts: the dreamed character is not a substitute for someone else; it is in some sense *both* characters at once. Existing accounts (§2.1) document this without explaining the specific structural form it takes.

On Speculation 1, identity bivalence is a direct consequence of topological preservation with geometric release. A person’s identity, considered structurally, decomposes into two layers. The first is geometric: specific facial features, biographical particulars, characteristic mannerisms. The second is topological: relational role within the dreamer’s experience—mother, employer, antagonist, intimate, authority. Under constraint relaxation on $\mathcal{F}$, the geometric layer deforms freely while the topological layer is preserved. The dreamed character therefore occupies the correct topological position (a “mother”) while its geometric realisation drifts to a face that happens to lie on a nearby fiber. The character is bivalent because the framework predicts exactly this: a topologically determined role realised by a geometrically free representative.

The reading is not symbolic. The framework does not claim the dreamed colleague *stands for* the mother in the manner of psychoanalytic substitution. It claims that the dreamed character occupies the same topological position as the mother, and that under the relaxed dynamics the geometric realisation of this position can drift across nearby fibers. The colleague’s face appears because the colleague’s face is, in geometric terms, on a fiber adjacent to the mother’s—not because the colleague *means* the mother.

7.2 Setting and Place Fusion

Dreamed settings frequently exhibit *compositional fusion*: a single dreamed location combines features of multiple remembered places, none of which it fully is. The phenomenon has been documented under the heading of incongruity [25, 41] and is among the most reliable structural features of dream content.

On the framework, fusion is a clause-(i) phenomenon applied to locations. A location’s structural role—enclosure, threshold, workspace, refuge, transit—is a topological feature; its geometric particulars—specific architecture, furniture, lighting, scale, orientation—are not. Trajectories on $\mathcal{F}$ can occupy a region whose topological role corresponds to a familiar location while its geometric realisation samples freely from nearby fibers containing other locations sharing similar topological roles. A childhood home and a current office can coincide in dream content because they share *enclosure-with-obligation* as topological structure; their geometric specifics merge freely under the relaxed dynamics.

Conjecture 1 adds a prediction. Locations whose topological role is robust across the dreamer’s life (long persistence: enclosure-with-care, threshold-of-judgment, workspace-of-task) should appear in dream reports with high probability and across long post-experience windows. Locations whose topological role is fragile or recently acquired (short persistence: a single visit, a stable but topologically peripheral location) should appear less frequently and only proximate to the originating experience.

7.3 Temporal Incoherence

Dream reports systematically describe temporal sequences that are locally coherent but globally violable. Scene transitions occur without continuous spatial-temporal trajectory; causal

sequences feel coherent within episodes but contradict each other across episodes. This is among the most distinctive features of dream phenomenology and one of the principal sources of bizarreness ratings [25]. Existing accounts attribute it variously to disconnection from external time-keeping cues, to weakened executive control, or to the cortex’s confabulatory construction over discontinuous activation [24]. None specifies the structural form of the incoherence.

On the framework, temporal incoherence reflects clause (i) applied to sequence structure. The ordering of events within an episode is partly topological: events are linked by causal arrows (this leads to that), and these connection relations are preserved. The specific temporal metric—which event occurred when, in what duration, on what continuous trajectory—is geometric. Under constraint relaxation, the topology of causal connection is preserved (the dream feels locally coherent because causal arrows still point) while the geometry of temporal metric deforms (scene transitions occur without continuous trajectory; durations stretch and compress; non-adjacent episodes do not need to be metrically consistent). The framework predicts what observation confirms: dreams preserve the topology of causal connection while letting the metric of temporal sequence deform freely.

7.4 Precognitive-Feeling Dreams

A class of dreams is reported as predictive: subjects describe dreams whose content appears to anticipate later waking events. The class is small but persistent across cultures [2] and resists dismissal as mere coincidence. Mystical explanations are unparsimonious; the framework supplies a non-mystical reading via Speculation 2.

On the framework, precognitive-feeling dreams arise from the cognitive system’s access during sleep to slow variables that real-time waking bandwidth does not admit. Weak somatic signals (early disease processes, accumulating fatigue, hormonal shifts), environmental regularities (gradual changes in domestic or workplace patterns), and social cues (incremental shifts in another person’s behaviour, accumulated micro-expressions) accumulate below the threshold of conscious attention during waking life. Relaxed exploration on $\mathcal{F}$, freed from real-time bandwidth allocation, samples regions of state space organised by these slow variables. Occasionally—when the accumulated slow variables happen to be predictive of nearer events—the resulting dream content is topologically similar to events not yet consciously anticipated.

The account requires no information about the future. It requires only earlier access, via a different sampling regime, to variables already present in the system. Two consequences distinguish the framework from mystical readings. First, precognitive-feeling dreams should preferentially occur during periods of elevated subliminal accumulation: impending illness with somatic premonitions, gradually shifting social dynamics, environmental changes registered without conscious attention. Second, the matched events should be those for which slow-variable signals exist and are within the cognitive system’s accumulation horizon (days to weeks), not arbitrary future events for which no current signal exists. Both consequences are testable; the latter constitutes the basis of Prediction 4 (§8).

8 Empirical Predictions

The framework is differentiated from competing accounts by the following predictions. Each requires operationalisation before becoming directly testable, and we sketch the form each test would take.

Prediction 1 (Asymmetric fidelity). In dream-report corpora coded for relational versus metric attributes, relational/topological attributes (containment, hierarchy, cycle) are preserved at higher fidelity to waking analogues than metric attributes (identity, size, duration), controlling for salience and recency.

Prediction 2 (Persistence ordering). When waking experiences are coded for cross-scale persistence of their structural features, longer-persistence features appear in dream reports with higher probability and over longer post-experience windows than shorter-persistence features.

Prediction 3 (Constraint-specific signatures). Pharmacological or neural perturbations that selectively relax one class of constraint (e.g., logical consistency vs. identity continuity) produce dream phenotypes with correspondingly restricted topological deformation rather than uniform degradation.

Prediction 4 (Slow-variable correlation). Reported precognitive-feeling dreams co-occur preferentially with periods of elevated subliminal sensory or affective signal accumulation, measurable independently of dream content.

Each prediction is risky: a clear failure of any one of them constitutes evidence against the framework.

9 Relation to Existing Accounts

Activation–synthesis. Stochastic activation may serve as the *driver* of trajectories in $\mathcal{F}$. The framework departs from activation–synthesis in holding that the resulting content is structurally non-random: $\mathcal{F}$ is constrained by the local topology of $\mathcal{M}_{\text{wake}}$, and the content inherits this constraint.

Memory consolidation. Replay phenomena correspond, on the framework, to traversals near $\mathcal{M}_{\text{wake}}$. The framework supplements consolidation accounts by explaining why off-manifold excursions feel meaningful: they retain topological isomorphism with waking content.

Psychoanalytic interpretation. The framework leaves room for affective and motivational content in dreams while reframing dream *form*: the generative process is topological, the symbolic content (where present) is downstream of it. The two accounts can in principle coexist as descriptions of different layers.

10 Open Problems

The framework opens four lines of work.

1. *Biological identification of Φ .* Which constraints bind waking cognition, and which are selectively relaxed during REM versus NREM? The framework predicts a partition of constraints by sleep stage; testing this requires linking neural correlates of specific constraints (sensorimotor coupling, logical consistency, identity continuity) to characteristic dream phenotypes.
2. *Empirical estimation of $\mathcal{F}$.* Manifold-learning methods applied to neural recordings should recover a tubular neighborhood of the waking manifold during sleep states. Successful recovery would constitute direct evidence for the framework’s central geometric claim.
3. *Coding scheme for persistence-graded preservation.* Persistent-homology comparison between waking experiences and dream reports requires a coding scheme that treats both as filtered simplicial complexes. Developing such a scheme is itself a substantive research task.
4. *Falsifiability boundary.* The framework should specify which concrete dream phenomena it is committed to ruling out. Without this specification, topological language risks accommodating too much. Drawing the boundary explicitly is a precondition for the framework’s full scientific status.

581 11 Conclusion

582 This paper has made two contributions. First, it has proposed a conjectural framework, assem-
583 bled from concepts in theoretical physics and algebraic topology, in which dreaming is described
584 as constrained exploration on a neighboring fiber of the waking cognitive manifold. Second, it
585 has used the framework to derive structural explanations for three distinctive features of dream
586 phenomenology: the simultaneous resemblance and difference between dream content and wak-
587 ing experience; the apparent meaningfulness of dream content; and the occasional appearance
588 of precognitive-feeling dreams.

589 The framework’s central claim—that dream content preserves topological structure of wak-
590 ing experience while releasing geometric specificity—is conjectural, and the four predictions of
591 §8 are the means by which it stands or falls. The framework’s wider claim is that the form
592 of dream generativity is illuminated by tools from topology and dynamical systems. This is a
593 substantive position on what dreams are, and it is offered as such.

594 References

- 595 [1] E. Aserinsky and N. Kleitman. Regularly occurring periods of eye motility, and concomitant
596 phenomena, during sleep. *Science*, 118(3062):273–274, 1953.
- 597 [2] K. Bulkeley. *Dreaming in the World’s Religions: A Comparative History*. New York
598 University Press, 2008.
- 599 [3] G. Carlsson. Topology and data. *Bulletin of the AMS*, 46(2):255–308, 2009.
- 600 [4] R. Cartwright. *The Twenty-Four Hour Mind: The Role of Sleep and Dreaming in Our*
601 *Emotional Lives*. Oxford University Press, 2010.
- 602 [5] K. Christoff, Z. C. Irving, K. C. R. Fox, R. N. Spreng, and J. R. Andrews-Hanna. Mind-
603 wandering as spontaneous thought: a dynamic framework. *Nature Reviews Neuroscience*,
604 17(11):718–731, 2016.
- 605 [6] F. Crick and G. Mitchison. The function of dream sleep. *Nature*, 304(5922):111–114, 1983.
- 606 [7] W. Dement and N. Kleitman. Cyclic variations in EEG during sleep and their relation to
607 eye movements, body motility, and dreaming. *Electroencephalography and Clinical Neuro-*
608 *physiology*, 9(4):673–690, 1957.
- 609 [8] D. C. Dennett. Are dreams experiences? *The Philosophical Review*, 85(2):151–171, 1976.
- 610 [9] S. Diekelmann and J. Born. The memory function of sleep. *Nature Reviews Neuroscience*,
611 11(2):114–126, 2010.
- 612 [10] G. W. Domhoff. *Finding Meaning in Dreams: A Quantitative Approach*. Plenum Press,
613 1996.
- 614 [11] G. W. Domhoff. *The Scientific Study of Dreams: Neural Networks, Cognitive Development,*
615 *and Content Analysis*. American Psychological Association, 2003.
- 616 [12] G. W. Domhoff. The neural substrate for dreaming: is it a subsystem of the default
617 network? *Consciousness and Cognition*, 20(4):1163–1174, 2011.
- 618 [13] G. W. Domhoff. *The Emergence of Dreaming: Mind-Wandering, Embodied Simulation,*
619 *and the Default Network*. Oxford University Press, 2018.

- 620 [14] H. Edelsbrunner and J. Harer. *Computational Topology: An Introduction*. American
621 Mathematical Society, 2010.
- 622 [15] N. Fenichel. Geometric singular perturbation theory for ordinary differential equations.
623 *Journal of Differential Equations*, 31(1):53–98, 1979.
- 624 [16] D. Foulkes. *Dreaming: A Cognitive-Psychological Analysis*. Lawrence Erlbaum Associates,
625 1985.
- 626 [17] D. Foulkes. *Children’s Dreaming and the Development of Consciousness*. Harvard University
627 Press, 1999.
- 628 [18] K. C. R. Fox, R. N. Spreng, M. Ellamil, J. R. Andrews-Hanna, and K. Christoff. The
629 wandering brain: meta-analysis of functional neuroimaging studies of mind-wandering and
630 related spontaneous thought processes. *NeuroImage*, 111:611–621, 2015.
- 631 [19] S. Freud. *Die Traumdeutung (The Interpretation of Dreams)*. Franz Deuticke, Leipzig and
632 Vienna, 1900.
- 633 [20] K. Friston. The free-energy principle: a unified brain theory? *Nature Reviews Neuroscience*,
634 11(2):127–138, 2010.
- 635 [21] C. S. Hall and R. L. Van de Castle. *The Content Analysis of Dreams*. Appleton-Century-
636 Crofts, 1966.
- 637 [22] E. Hartmann. Outline for a theory on the nature and functions of dreaming. *Dreaming*,
638 6(2):147–170, 1996.
- 639 [23] E. Hartmann. *Dreams and Nightmares: The New Theory on the Origin and Meaning of*
640 *Dreams*. Plenum Press, 1998.
- 641 [24] J. A. Hobson and R. W. McCarley. The brain as a dream state generator: an activation–
642 synthesis hypothesis of the dream process. *American Journal of Psychiatry*, 134(12):1335–
643 1348, 1977.
- 644 [25] J. A. Hobson, S. A. Hoffman, R. Helfand, and D. Kostner. Dream bizarreness and the
645 activation–synthesis hypothesis. *Human Neurobiology*, 6(3):157–164, 1987.
- 646 [26] J. A. Hobson, E. F. Pace-Schott, and R. Stickgold. Dreaming and the brain: toward a
647 cognitive neuroscience of conscious states. *Behavioral and Brain Sciences*, 23(6):793–842,
648 2000.
- 649 [27] J. A. Hobson. REM sleep and dreaming: towards a theory of protoconsciousness. *Nature*
650 *Reviews Neuroscience*, 10(11):803–813, 2009.
- 651 [28] J. A. Hobson and K. J. Friston. Waking and dreaming consciousness: neurobiological and
652 functional considerations. *Progress in Neurobiology*, 98(1):82–98, 2012.
- 653 [29] E. Hoel. The overfitted brain: dreams evolved to assist generalization. *Patterns*,
654 2(5):100244, 2021.
- 655 [30] T. Horikawa, M. Tamaki, Y. Miyawaki, and Y. Kamitani. Neural decoding of visual imagery
656 during sleep. *Science*, 340(6132):639–642, 2013.
- 657 [31] C. G. Jung. On the nature of dreams. In *The Collected Works of C. G. Jung*, volume 8
658 (*The Structure and Dynamics of the Psyche*). Princeton University Press, 1948/1960.

- 659 [32] D. Kahn, E. F. Pace-Schott, and J. A. Hobson. Emotion and cognition: feeling and
660 character identification in dreaming. *Consciousness and Cognition*, 11(1):34–50, 2002.
- 661 [33] S. LaBerge. *Lucid Dreaming*. Tarcher, 1985.
- 662 [34] S. LaBerge. Lucid dreaming: evidence and methodology. *Behavioral and Brain Sciences*,
663 23(6):962–964, 2000.
- 664 [35] S. Llewellyn. Such stuff as dreams are made on? Elaborative encoding, the ancient art of
665 memory, and the hippocampus. *Behavioral and Brain Sciences*, 36(6):589–607, 2013.
- 666 [36] S. Llewellyn. Crossing the invisible line: de-differentiation of wake, sleep and dreaming
667 may engender both creative insight and psychopathology. *Frontiers in Psychology*, 7:73,
668 2016.
- 669 [37] N. Malcolm. *Dreaming*. Routledge & Kegan Paul, 1959.
- 670 [38] J. E. Malinowski and C. L. Horton. Memory sources of dreams: the incorporation of
671 autobiographical rather than episodic experiences. *Journal of Sleep Research*, 23(4):441–
672 447, 2014.
- 673 [39] T. Metzinger. *Being No One: The Self-Model Theory of Subjectivity*. MIT Press, 2003.
- 674 [40] E. F. Pace-Schott. The frontal lobes and dreaming. In D. Barrett and P. McNamara, editors,
675 *The New Science of Dreaming, Volume 1: Biological Aspects*, pages 115–154. Praeger, 2007.
- 676 [41] A. Revonsuo and C. Salmivalli. A content analysis of bizarre elements in dreams. *Dreaming*,
677 5(3):169–187, 1995.
- 678 [42] A. Revonsuo. The reinterpretation of dreams: an evolutionary hypothesis of the function
679 of dreaming. *Behavioral and Brain Sciences*, 23(6):877–901, 2000.
- 680 [43] M. Schredl. Dream recall frequency: a useful measure for assessing dreaming? *International*
681 *Journal of Dream Research*, 1(1):1–3, 2008.
- 682 [44] M. Schredl and D. Doll. Emotions in diary dreams. *Consciousness and Cognition*, 7(4):634–
683 646, 1998.
- 684 [45] F. Siclari, B. Baird, L. Perogamvros, G. Bernardi, J. J. LaRocque, B. Riedner, M. Boly,
685 B. R. Postle, and G. Tononi. The neural correlates of dreaming. *Nature Neuroscience*,
686 20(6):872–878, 2017.
- 687 [46] M. Solms. *The Neuropsychology of Dreams: A Clinico-Anatomical Study*. Lawrence Erl-
688 baum Associates, 1997.
- 689 [47] M. Solms. Dreaming and REM sleep are controlled by different brain mechanisms. *Behav-*
690 *ioral and Brain Sciences*, 23(6):843–850, 2000.
- 691 [48] M. Solms and O. Turnbull. *The Brain and the Inner World: An Introduction to the*
692 *Neuroscience of Subjective Experience*. Other Press, 2002.
- 693 [49] B. O. States. *The Rhetoric of Dreams*. Cornell University Press, 1992.
- 694 [50] B. O. States. *Dreaming and Storytelling*. Cornell University Press, 1993.
- 695 [51] R. Stickgold, J. A. Hobson, R. Fosse, and M. Fosse. Sleep, learning, and dreams: off-line
696 memory reprocessing. *Science*, 294(5544):1052–1057, 2001.
- 697 [52] R. Stickgold. Sleep-dependent memory consolidation. *Nature*, 437(7063):1272–1278, 2005.

- 698 [53] I. Strauch and B. Meier. *In Search of Dreams: Results of Experimental Dream Research*.
699 SUNY Press, 1996.
- 700 [54] J. Tuominen, T. Stenberg, A. Revonsuo, and K. Valli. Social contents in dreams: an
701 empirical test of the social simulation theory. *Consciousness and Cognition*, 69:133–145,
702 2019.
- 703 [55] U. Voss, R. Holzmann, I. Tuin, and J. A. Hobson. Lucid dreaming: a state of consciousness
704 with features of both waking and non-lucid dreaming. *Sleep*, 32(9):1191–1200, 2009.
- 705 [56] U. Voss, R. Holzmann, A. Hobson, W. Paulus, J. Koppehele-Gossel, A. Klimke, and M. A.
706 Nitsche. Induction of self awareness in dreams through frontal low current stimulation of
707 gamma activity. *Nature Neuroscience*, 17(6):810–812, 2014.
- 708 [57] M. A. Wilson and B. L. McNaughton. Reactivation of hippocampal ensemble memories
709 during sleep. *Science*, 265(5172):676–679, 1994.
- 710 [58] J. M. Windt. The immersive spatiotemporal hallucination model of dreaming. *Phenomenol-*
711 *ogy and the Cognitive Sciences*, 9(2):295–316, 2010.
- 712 [59] J. M. Windt. *Dreaming: A Conceptual Framework for Philosophy of Mind and Empirical*
713 *Research*. MIT Press, 2015.