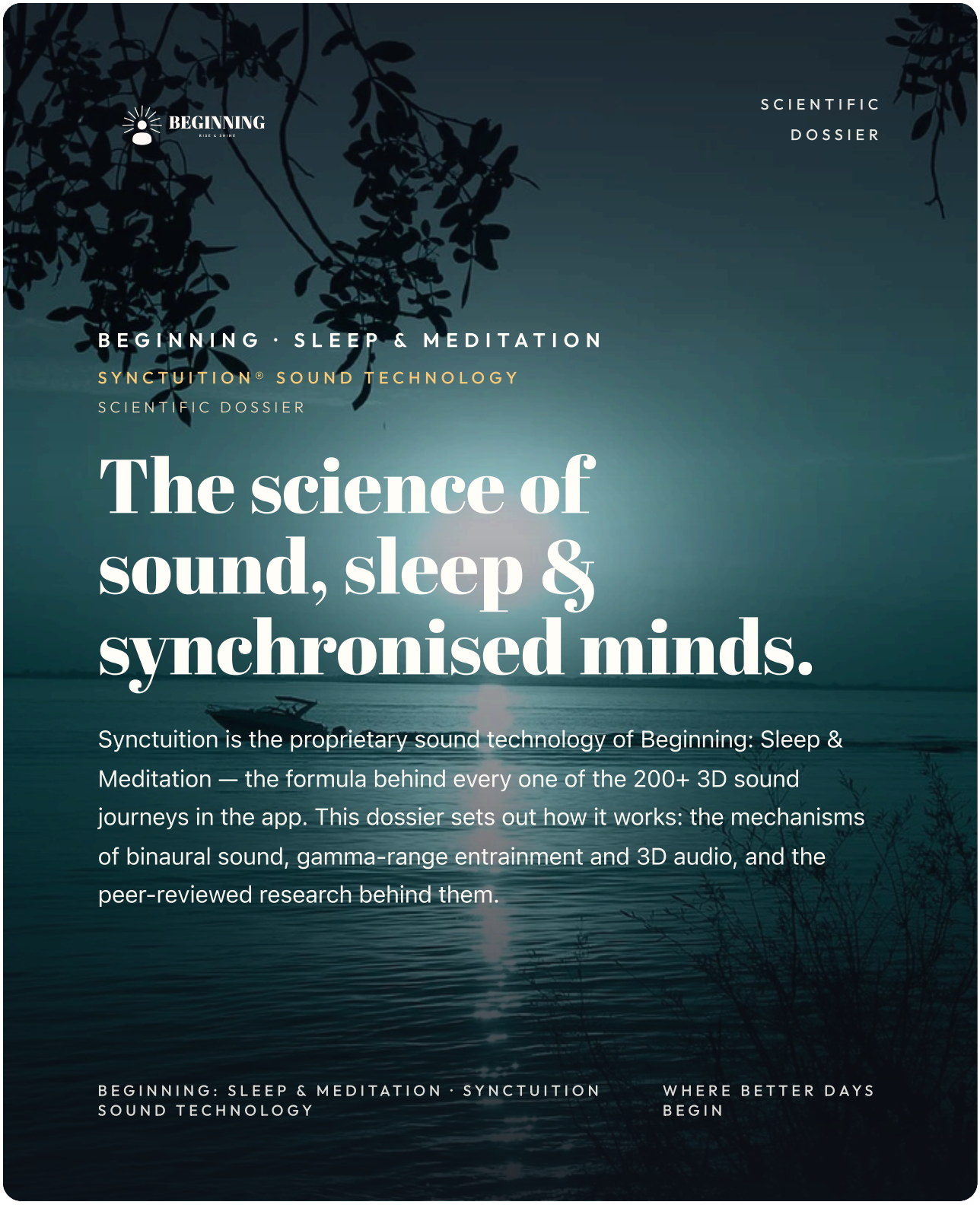

BEGINNING
RISE & SHINE
SCIENTIFIC
DOSSIER
BEGINNING · SLEEP & MEDITATION
SYNCTUITION® SOUND TECHNOLOGY
SCIENTIFIC DOSSIER
The science of sound, sleep & synchronised minds.
Synctuition is the proprietary sound technology of Beginning: Sleep & Meditation — the formula behind every one of the 200+ 3D sound journeys in the app. This dossier sets out how it works: the mechanisms of binaural sound, gamma-range entrainment and 3D audio, and the peer-reviewed research behind them.
BEGINNING: SLEEP & MEDITATION · SYNCTUITION SOUND TECHNOLOGY
WHERE BETTER DAYS BEGIN

OVERVIEW

How Synctuition works

Synctuition, Beginning's proprietary sound technology, is an audio tool for the synchronisation of the brain's two hemispheres, achieved through the entrainment and amplification of neural oscillations that occur mostly within the gamma-frequency range. It works entirely through the brain's auditory system. What follows is a plain-language account of the mechanisms — binaural beats, gamma oscillations, 3D sound, rhythmic entrainment, sleep and neuroplasticity — followed by the full list of scientific references.

BEGINNING & SYNCTUITION

Synctuition is the name of Beginning's sound technology — our unique audio formula, developed and recorded over 15 years. It is part of every journey in Beginning: Sleep & Meditation, and it's the first thing you hear: each journey opens with the words “Welcome to Synctuition.”

MECHANISM · 01

Brain synchronisation through hearing

Synctuition is an audio tool for the synchronisation of the brain's hemispheres, achieved through the entrainment and amplification of neural oscillations that occur mostly within the range of gamma-frequency brain waves. It works through the brain's auditory system. Hearing sound requires cooperation from many brain regions that interact through a complex and dynamic neural network. Auditory signals initiate a cascade of neural activity throughout the whole brain — from the lowest reflexes to the highest levels of cognitive action.

This is how the brain perceives sound

The auditory brainstem response begins at the cochlea — the sense organ in the inner ear that translates sound into nerve impulses. Sound processing continues in the central nervous system on three levels: in the brainstem as a reflex, in the auditory cortex (part of the temporal lobe, located bilaterally in both hemispheres), and in other remote areas of the brain used to process the audio stimuli. The auditory brainstem response occurs in the first 10 milliseconds; the arrival of information to the brainstem triggers reflexes and subconscious processes.

In the brainstem, auditory information is decoded into basic components such as frequency and duration, then passed to the thalamus, which acts as a neural information hub — relaying and integrating sensory and motor signals to the cerebral cortex, and participating in the regulation of consciousness, sleep and alertness. The thalamus passes the information to the primary auditory cortex, located bilaterally in both hemispheres, where the wave signals are recognised and processed.

In addition to the primary pathway, alternative non-primary auditory pathways process all sorts of sensory messages. Their function is to "choose" which sensory messages are treated first — giving us the ability to focus only on certain sounds, or to ignore them, such as reading a book while listening to music.

MECHANISM · 02

Why gamma-range binaural beats

The auditory cortex provides distinctly powerful responses in the gamma-frequency range of sound. The reason is that gamma frequencies are resonant frequencies of certain areas of the brain. The different gamma-range binaural frequencies and entrainment patterns used in Synctuition affect the brain through the same auditory pathways and mechanisms that affect different neurons — because the auditory cortex and other centres involved in processing auditory information use different sets of neurons to decode sounds of different pitch.

Neurons in local populations process information, whereas larger neural assemblies — including neurons connected across separate brain areas — combine the multiple processes important for higher-level cognitive tasks. These neural oscillations promote transient network interactions responsible for complex cognition. Gamma-range binaural beats and 3D sounds provide an extremely powerful synchronising effect on brainwave patterns, because the auditory cortices are located in different hemispheres and must work very closely together to decode the 40 Hz binaural signal you are listening to in the Synctuition journeys. The right auditory cortex is more sensitive to tonality, the left to minute sequential differences in sound; Synctuition uses these properties to provide an even more immersive experience.

Oscillators in one brain region can phase-synchronise with oscillators in another through the long-range connections created by listening to Synctuition. As neurons oscillate, they effectively open and close their window to send and receive information: for information to transfer from one neuronal group to another, the sending neuron must be excitable at the same time as the receiving group. This coupling of oscillations, through brainwave synchronisation, allows efficient neural communication — the transient coupling of neurons firing synchronously to form a functional neural network.

Listening to the gamma-range binaural-beat frequencies in Synctuition increases connections in the brain through neural plasticity, using the auditory-cortex-initiated phase synchronisation of brain networks. As a result of this enhanced plasticity, Synctuition accelerates intuitive and communicative processes by creating new synaptic connections between different regions of the brain.

MECHANISM · 03

The Synctuition wave formula

The Synctuition wave formula is a composition of natural 3D sounds and rhythmic entrainment frequencies; some of the component sounds intentionally coincide with the neural oscillations of the gamma band. The representing function S is a superposition of w component waves $\Psi(n_x, t_x)$, each an

acoustic wave function (for 3D spherical waves) at the spatial position *n* of the component:

$$S(n_1, n_2, \ldots, n_w, t_1, t_2, \ldots, t_n) = \Sigma_{i=1}^{w} \Psi(n_i, t_i) = \Psi(n_1, t_i) + \Psi(n_2, t_i) + \ldots + \Psi(n_w, t_i)$$

$$\Psi(n, t) = \int_{-\infty}^{\infty} \Psi(n, \omega)\, e^{-i\omega t}\, d\omega$$

The component waves Ψ_n of the Synctuition wave are drawn from computer-generated or natural sources, such as rhythmic entrainment frequencies or natural sounds. The difference between natural and artificial sound waves, in the context of the formula, is the intrinsic dimensionality of the wave Ψ_n — here calculated as a Hausdorff dimension of the sound wave:

$$D = -\log_{\varepsilon} N = -\left(\log N / \log \varepsilon \right)$$

where *D* is the Hausdorff dimension (approximation), *N* the number of repeating units and *ε* the scaling factor. The value of *D* for a synthetic sound wave approaches an integer, while for natural sounds it is a fractional number. The Hausdorff dimension of the sound wave can also be seen as an entropy of the sound.

MECHANISM · 04

Binaural beats

Binaural beats, or binaural tones, are auditory processing artefacts — apparent sounds caused by specific physical stimuli. A binaural beat is the auditory effect perceived when two different pure-tone sine waves are presented separately to each ear. The effect on brainwaves depends on the frequency difference between the tones: if 300 Hz is played in one ear and 310 Hz in the other, the binaural beat has a frequency of 10 Hz. Synctuition uses binaural beats in the gamma ~40 Hz range. The beat is not a physical property of the sound, but the convergence of neural activity from the two ears in the central binaural auditory pathways of the brain.

Entrainment & memory

Human electroencephalography (EEG) activity can be entrained by rhythmic sensory stimulation. Stimulus-related responses are observed at modulation rates up to 200 Hz, with the largest responses recorded at approximately 40 Hz. Phase synchronisation has been shown to play a major role in cognitive processes, in particular in memory operations. As a practical application, it has been demonstrated that long-term memory performance can be modulated by weak electric in-phase versus antiphase stimulation of the rhinal cortex and hippocampus — among other deep-brain-stimulation approaches to memory enhancement. These findings suggest a role for binaural beats in memory enhancement. *— Becher et al., 2015*

Relaxation & de-stress

Findings from a double-blind, placebo-controlled study demonstrate a role for binaural beats in facilitating access to more restorative states of post-exercise relaxation, with subtle yet somewhat durable psychophysiological effects. Twenty minutes of exposure to binaural beats significantly increased a known marker of parasympathetic activation — driven by activity in the anterior cingulate and medial prefrontal cortex. Research subjects reported being significantly more relaxed while listening to binaural beats than while listening to a placebo. *— McConnell et al., 2014*

MECHANISM · 05

Binaural gamma waves

Science has discovered a strong correlation between transcendental mental states and gamma waves. A gamma wave is a pattern of neural oscillation in humans with a frequency between 25 and 100 Hz. Gamma oscillations act in the cortex to bind modality-specific perceptual representations, and in the hippocampus to bind rich perceptual and contextual information from diverse brain regions into episodic representations. Gamma waves can activate experiences of the past and reveal forgotten experiences stored in memory. The set of experiences we use for decision-making is smaller than the actual set stored in memory; the revealed experiences significantly increase the probability of accurate intuitive decisions.

Gamma oscillations allow interaction between cortical structures and the hippocampus for the encoding and retrieval of episodic memories. Phase synchronisation between cortical and hippocampal neurons — and between hippocampal neurons themselves — provides the mechanism by which individual episodic-memory representations from diverse cortical regions are encoded into hippocampal representations.

The mechanism of gamma rhythmic firing

Rhythmic firing can occur because of the intrinsic firing patterns of excitatory principal cells or common input from a pacemaker such as the thalamus; more commonly in the cortex and hippocampus it is an emergent property of interactions between excitatory principal cells and inhibitory interneurons, whose collective activity leads to neurons firing together and being inhibited together. Gamma rhythmic firing arises specifically through the interaction of excitatory principal cells and fast basket-cell inhibitory interneurons. It modulates perceptual feature binding — just as visual perception integrates several features into a whole, episodic memory integrates several individual representations — and provides the precise timing necessary for spike-timing-dependent plasticity. During a cognitive task, gamma oscillations let local neurons fire synchronously at high frequencies; multiple processes are then combined through large-scale brain networks whose oscillations become phase-synchronised. *— Nyhus & Curran, 2010*

MECHANISM · 06

3D sound

Synctuition has been created with a specially developed 3D recording technology that lets the listener enjoy a spatially accurate soundscape through normal stereo headphones, with a correct dimensional perception of the sound source in the recording field. The broad mechanism of 3D sound perception has two parts: the detection of timing differences between the ears, and spectral differences between the ears.

Natural 3D sounds

Natural 3D sounds are recorded spatially in wild nature without synthetic components. They are restricted to natural sources in their normal soundscape and presented to the listener with the correct timing and spectral differences found in nature — delivering an authentic experience that makes the brain react as if the audio stimulus is coming live from nature.

3D music

3D music recordings include human-produced sounds made using instrumental or vocal techniques, or sounds derived from other anthropogenic sources.

Intuitive instrumental & vocal music

Synctuition's music is based on intuitive improvisations of instrumental and vocal music, performed extemporaneously in a meditative state of mind. Intuitive music is a creative act of immediate composition — combining performance with the communication of emotion, instrumental technique and spontaneous responses to inspiration. Its manifestations are spontaneous actions of the meditative mind, though they can also be initiated by external stimuli. All music used in Synctuition is intuitive music: a performance without any pre-set structure or harmonic limitation, flowing straight from the subconscious. In cognitive terms, improvisation is the spontaneous generation, selection and execution of novel auditory–motor sequences. *— Berkowitz & Ansari, 2008*

MECHANISM · 07

Rhythmic entrainment frequencies

Rhythmic entrainment constitutes a key source of the emotions experienced during music listening. Different bodily rhythms can synchronise to those present in music, generating emotional feelings via proprioceptive feedback mechanisms; corticospinal excitability is increased during metrically strong rhythmical sequences. The basal ganglia integrate rhythmical information with both the cognitive and affective components of musical experience, while cross-modal influences recruit cortical areas in the posterior parietal lobule — so parietal attention systems contribute to the effect musical rhythm has on attention and entrainment. *— Trost & Vuilleumier, 2013*

The effect of temporal entrainment on motor function through rhythmic auditory stimuli is well established in motor learning and therapeutic rehabilitation. Temporally structured learning templates, inherent in most music, enhance learning and provide the temporal structure for information encoding.

Rhythmic motor synchronisation involves changes in the activation of prefrontal and parietal networks: during isochronous synchronisation prefrontal areas are activated, whereas tracking tempo-modulated patterns progressively recruits medio-, ventro- and dorsolateral areas of the prefrontal cortex. Spatial patterns of neural synchronisation change with the duration of working memory, possibly indicating a shift from phonological to semantic encoding, and long-term recall of music shows additional local network coherence in the gamma band across right anterior and posterior networks. Neuronal synchronisation assembles the coupled networks associated with effective learning; brain plasticity tied to behavioural learning thus depends critically on the precise temporal coding of neuronal responses. Special melodic–rhythmic structures in music enhance memory performance by mapping temporal order onto the learning information. *— Thaut, Peterson & McIntosh, 2005*

MECHANISM · 08

Combination of the waves

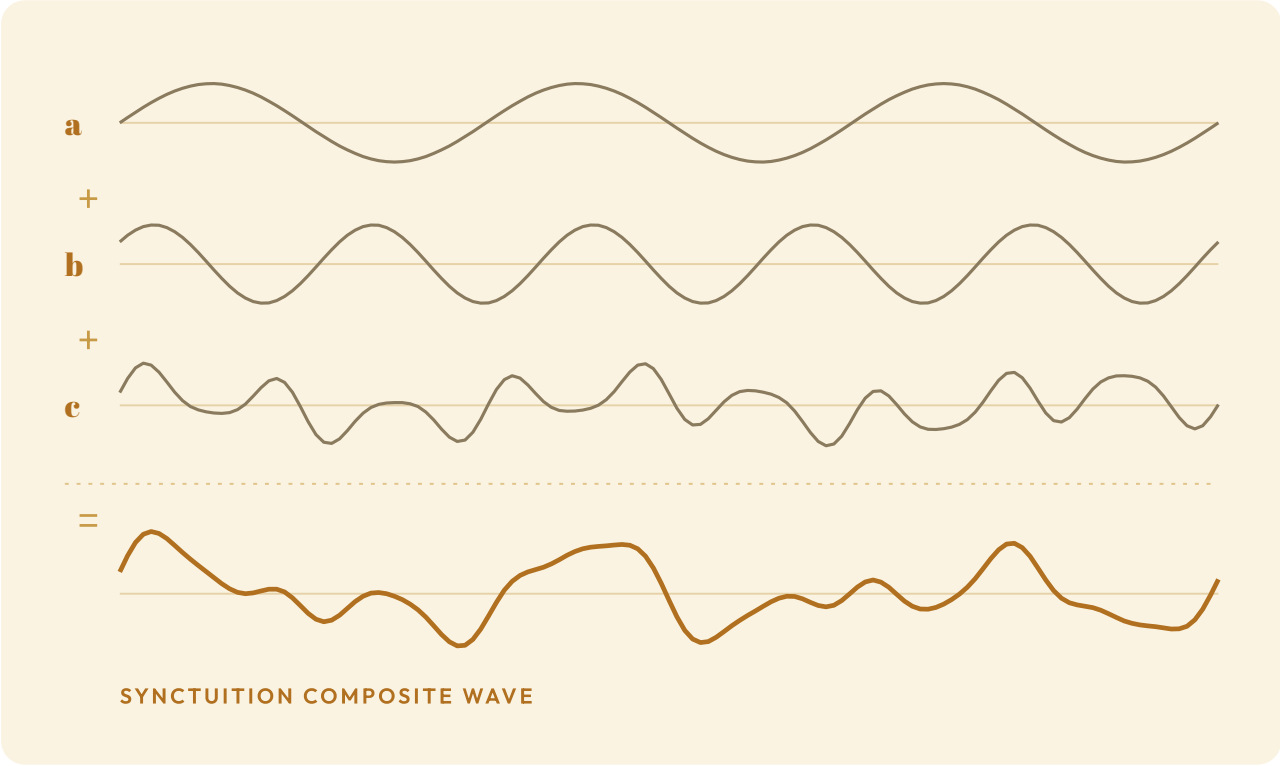


Illustration of the Synctuition formula operation principle. The input sound waves (a), (b) and (c) are combined into the composite Synctuition sound wave.

The input sound waves — natural 3D recordings, rhythmic entrainment frequencies and intuitive music — are combined by the Synctuition wave formula into a single composite sound wave. Each component contributes its own spatial position and intrinsic dimensionality, producing a layered soundscape that carries both the natural, fractional-dimension textures of nature and the precisely tuned entrainment frequencies of the gamma band.

APPLICATION · 09

Why listen before sleep

Why we need to sleep seems clear: without it we become tired and irritable and the brain functions less well, while after a good night's sleep the brain and body feel refreshed and restored. The synaptic homeostasis hypothesis (SHY) proposes that the fundamental function of sleep is the restoration of synaptic homeostasis — the balance challenged by the synaptic strengthening that learning drives during waking hours, and by synaptogenesis during development. In other words, sleep is "the price we pay for neuroplasticity": by renormalising synaptic strength it reduces the burden of plasticity on neurons while restoring neuronal selectivity and the ability to learn, enhancing signal-to-noise ratios and leading to the consolidation and integration of memories. Sleep also supports learning and memory by acting on synapses through molecular mechanisms. *— Diering et al., 2017*

Synctuition's audio technology helps the listener fully relax the body and calm the electrical storm in the brain before sleep, through binaural 3D audio meditation — supporting considerably better rest through the night. Sleep protects memories and makes them easier to access: a good night's sleep promotes access to memory traces that were initially too weak to be retrieved, and compared with wakefulness it helps recall and reprocess unrecalled memories for use or long-term storage. While we sleep, the brain actively repeats the information it considers important and makes memories accessible in a wider range of contexts. The main factor behind this sleep-related memory boost is the hippocampus, which stores recently experienced information.

FOUNDATIONS · 10

Intuition & neuroplasticity

As magical as it seems, intuition is actually a set of complex neural processes involving the whole brain — from sensory inputs and low-level reflexes to high-level cognition. It is the brain's ability to solve difficult or seemingly impossible problems as very complex logical inferences, where sensory inputs together with existing memories act as premises and intuitive thoughts are the results. Every problem-solving task needs "computational" capability, but intuition needs it remarkably more, despite usually happening unconsciously. For problem solving the brain uses neural networks, usually grouped by task in specific areas; their composition is not constant but changes throughout life as the brain builds new connections and alters or removes existing ones — the process called neuroplasticity.

To solve some problems, networks from different areas must cooperate as synchronously as possible; for intuition the neural processes are more complex still, and both hemispheres must be equally involved. The hemispheres are like mirror images, but not completely — they work nearly in sync yet have subtle differences that can reduce communication between them and hamper intuitive thinking.

What is neuroplasticity?

Neuroplasticity is the process by which experience reorganises the brain's neural pathways; long-lasting functional changes occur when we learn or memorise new information. Individual synaptic connections are constantly removed or recreated, largely depending on the activity of the neurons that bear them — captured in Hebbian theory as "neurons that fire together, wire together; neurons

that fire out of sync, fail to link." If two nearby neurons often fire in close temporal proximity their functional properties may converge; neurons rarely activated together are more likely to diverge. As the neuroscientist Siegrid Löwel summarised, "cells that fire together, wire together." Plasticity can thus be viewed as either the strengthening of a connection or an increase in efficiency, where synaptic strength is the ability to elicit a response in the postsynaptic cell and efficiency the ability of that cell to be excited by the presynaptic one.

Homeostatic synaptic plasticity

Homeostatic plasticity stabilises the activity of a single neuron or a neuronal circuit when perturbations alter excitability, keeping action-potential output within an optimal range. It is believed to operate on at least two levels: one residing at the individual synapse, the other operating cell-wide to maintain metabolic stability while keeping synaptic connections constant. Its principal models include synaptic scaling, the Bienenstock–Cooper–Munro (BCM) synapse, spike-timing-dependent plasticity (STDP), the regulation of intrinsic excitability and synaptic redistribution. Synaptic scaling adjusts the strength of all synapses on a postsynaptic neuron in response to changes in average postsynaptic activity — the term arising from the observation that a perturbation to network activity generates compensations that return, or "scale," average firing rates back to control values. *— Cohen et al., 2017*

THE EVIDENCE

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