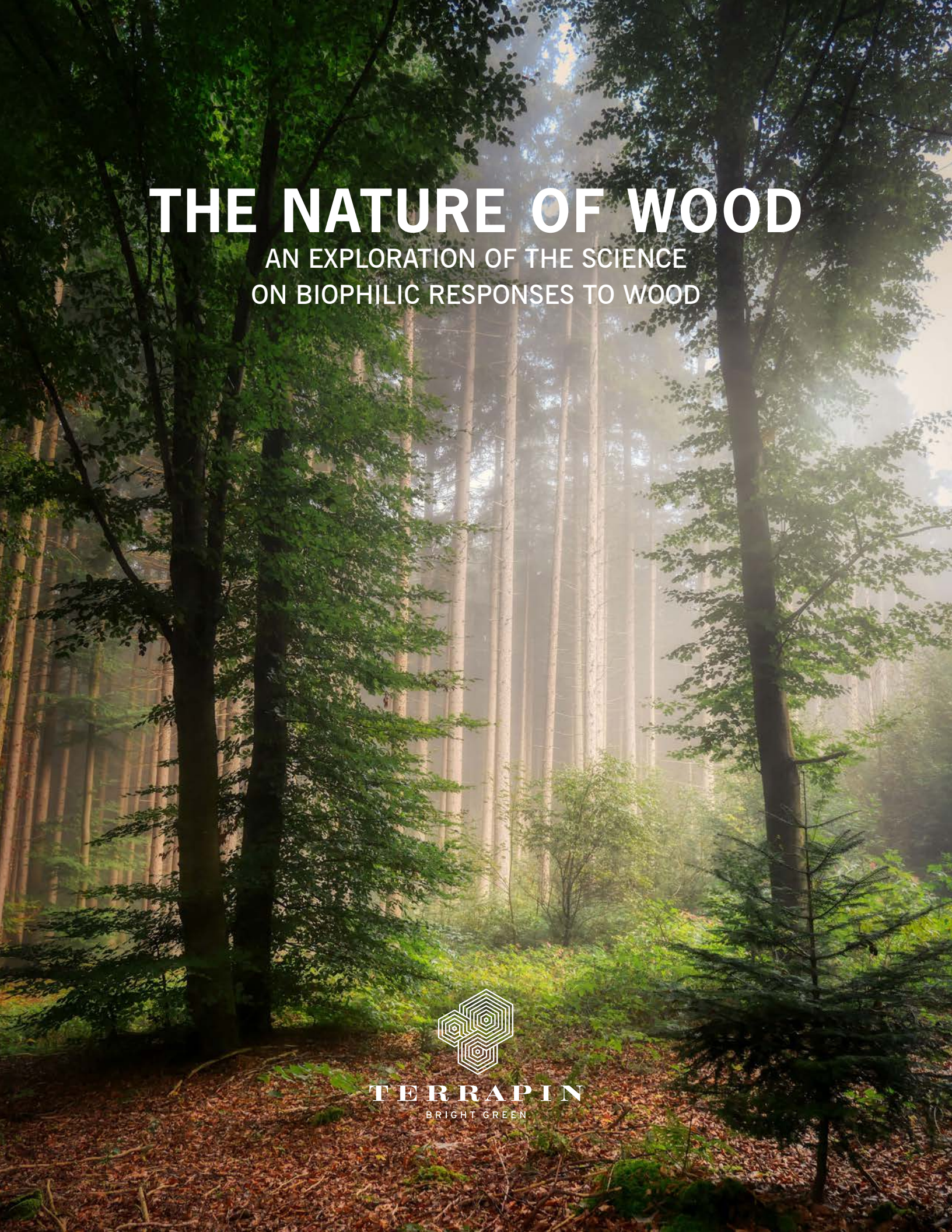

THE NATURE OF WOOD

AN EXPLORATION OF THE SCIENCE ON BIOPHILIC RESPONSES TO WOOD

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ACKNOWLEDGEMENTS

Terrapin would like to thank Forest Innovation Investment® of British Columbia and Softwood Lumber Board® of Oregon for sponsoring this effort. We would also like to thank the following individuals for their industry research insights and guidance. The opinions and conclusions in this report are solely those of the authors and do not necessarily reflect the views of the sponsors and advisors.

SPONSOR LEADERSHIP

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Cees de Jager	Softwood Lumber Board

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Reference: William D. Browning, Catherine O. Ryan, & Claire DeMarco (2022). The nature of wood, an exploration of the science on biophilic responses to wood. New York: Terrapin Bright Green, LLC. http://www.terrapinbrightgreen.com/report/the-nature-of-wood

Key words: wood grain, fractals, natural patterns, biophilia, associative processing

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THE NATURE OF WOOD

AN EXPLORATION OF THE SCIENCE ON BIOPHILIC RESPONSES TO WOOD

Mass timber construction is gaining attention in the architectural world. Timber construction can have significant benefits in reducing the embodied carbon footprint of buildings. If sourced from sustainably managed forests and produced locally, these building components can store more carbon than is emitted in their production.[1] In effect, the mass timber portions of a building could offset the carbon footprint of other materials[2, 3]—a significant achievement for green building. That said, another major reason for the attention to mass timber likely is that we find wood to be natural and beautiful.[4] By asking why we prefer wood, this paper explores the science of having a 'biophilic' response to wood.

PORTLAND AIRPORT TERMINAL

The choice of wood for the structure of the PDX Terminal Redevelopment in Portland, Oregon, had three main drivers: a desire to celebrate local nature, history, culture and business; to improve the embodied carbon and sustainability profile for the building; and to optimize the impact of the biophilic experience for occupants.

Rendering: courtesy ZGF Architects

INTRODUCTION TO BIOPHILIA

Humans seem to have an innate affinity for nature—a phenomenon known as biophilia.[5] This connection has become the subject of many research initiatives exploring how different experiences of nature affect humans both physiologically and psychologically, leading to the recognition that designing elements of nature into the built environment can have health benefits including stress reduction, improved cognitive performance, enhanced moods, and increased preference for spaces.[6] These benefits are often referred to as 'biophilic responses'.

EXPERIENCE OF NATURE

Experiences of nature in the built environment tend to fall into three broad categories which have been called Nature in the Space, Natural Analogues, and Nature of the Space.[7] **Nature in the Space** refers to direct experiences of nature and natural processes in the built environment. These include views to landscape, the presence of living plants, animals, water, sunlight, breezes, and the changing seasons.

Natural Analogues refers to indirect experiences of nature in the built environment. These include collinear and biomorphic forms, natural materials, and a level of complexity and order through materials or patterns, such as fractals.

Nature of the Space refers to experiences induced by certain three dimensional characteristics of spaces. These include distant views through a space, spaces that provide refuge and retreat, spaces that compel exploration, spaces that have an element of risk and peril, and spaces that induce awe.

RESEARCH

Research into the causality of the many positive biophilic responses to these experiences of nature is an expanding field that draws from disciplines of environmental psychology, evolutionary psychology, endocrinology, and neuroscience.

Early biophilia research focused on the responses to viewing and experiencing natural environments.[8] One of the best known studies found that having a view to nature led to better healing outcomes among hospital patients.[9] Research has also suggested that humans have a preference for views to savannah habitats with trees and, specifically, shade trees like those on the African savannah.[10] Through guided walks in forests in

FOREST BATHING

A walk in the woods can lead to a measurable drop in cortisol, a stress hormone. This effect persists for hours after the forest bathing experience.

Photo: Kaif Muhammed courtesy Unsplash

BIOPHILIC BENEFITS OF WOOD

There are a range of meaningful physiological and psychological benefits of being in a space with wood products and surfaces.

- Lowered pressure and lowered heart rate
- Increased activation of the parasympathetic nervous system/calming
- Perception of warmth
- Expressed visual preference for the space
- Wood is perceived to be connected to living things

Photo: Nachelle Nocom courtesy Unsplash

Japan and Korea, researchers have been exploring Shinrin-yoku (Forest Bathing) in conjunction with impacts on stress reduction[11] and immune system function.[12, 13]

Research continues to indicate that nature-made and human-made objects and environments are processed differently in our brains. Humans subconsciously sort between naturally occurring and anthropogenic creations, and seem to prefer those that are nature-made.[14] Similarly, humans subconsciously sort between the motion patterns of living versus mechanical, processing each of the two in different areas of the brain.[15] This intuitive sorting occurs with our other senses as well. When a sound is associated with nature it is processed in a different part of the brain than sound from a machine, also influencing which is a preferred experience.[16]

While wooden objects are crafted by humans – a process that is often considered manufactured or unnatural – the wood itself is still considered to be "natural",[17] which may hint at why research suggests we like having wood around us in buildings.[18] Wood has been used in the construction of shelter and artifacts for thousands of years in cultures around the world. It historically has been a plentiful resource that is readily shaped by simple tools. Today there are a host of human-made materials that are available for construction, interior finishes, and furniture; so why is it that we continue to prefer wood?

PREFERENCES FOR WOOD

Wood is often described by research participants as being "warm, comfortable, relaxing, natural, and inviting" and people believe that "wood can help to create healthful environments".[19] Some experimental work has investigated biophilic responses to wood, much of which is focused on response to wood as a visual element within an interior space. The visual presence of wood in a room is known to lead to perceptions of warmth.[20] In a room with white walls, the addition of wood surfaces has shown to lower stress more effectively than the addition of a few plants.[21] In other research, rooms with (about 45% of the) surfaces being wood have shown to boost perceptions of comfort and lower blood pressure,[22] even among study participants who expressed a dislike for the wood.[23] Our sense of touch and smell are also suggested to induce biophilic responses to wood—through haptic and olfactory experiences.

HAPTIC EXPERIENCE

The entry at Vancouver Island University features Douglas Fir slabs and door pulls. The texture of the wood is the first thing people feel when they engage with the building.

Photo: courtesy naturallywood.com

OLFACTORY EXPERIENCE

In the design of Common Ground High School in New Haven, Connecticut, Gray Organschi Architecture used a variety of wood construction techniques. A comment by the students is that they like the smell of the wood in the building.

Photo: David Sundberg/ESTO Photographics

HAPTIC EXPERIENCE

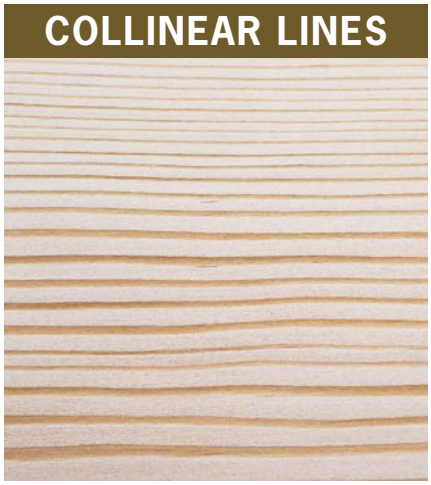
Unique from visual and olfactory (and auditory) sensory experiences, the haptic (sense of touch) experience of wood is about its tangibility and our perception of that sense of touch. In a blindfolded experiment, participants placed their palm on a panel of stainless steel, tile, marble or white oak; touching the oak panel led to increases in activity of the parasympathetic (rest and calming) portion of the nervous system that did not occur with the other materials.[24] Haptic experiences of wood are also evidenced to lower blood pressure rates.[25, 26] These results may be due to wood having lower thermal conductance than metal or stone, and therefore feels closer to the perceived ambient temperature of a space.

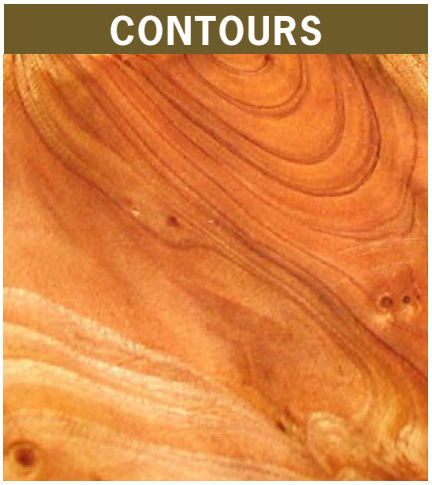
OLFACTORY EXPERIENCE

Scent offers another dimension to the experience of wood. Olfactory signals are processed incredibly fast,[27] and are a powerful trigger for retrieving memories.[28] Much of the Shinrin-yoku research has taken place in Korean forests planted with Japanese Hinoki cypress trees.[29] These trees are esteemed for their scent, which is known to linger with objects made from the cypress wood, and reportedly produces a calming effect[30] that can be measured through changes in heart rate and other variables.[31] Similarly, research has found that linalool, a predominant compound in the scent of lavender, triggers in mice the same neural pathways as Valium.[32] Could the scent of wood trigger something similar in our brain? Incidentally, a study of respiratory response and heart rate among participants who slept in a bed made of fragrant stone pine showed significant physiological improvements compared to those in a bed made of chipboard covered in melamine; the researchers attributed this outcome to the conifer resins, including limonene.[33]

The Forest, a store design by Kengo Kuma & Associates for Valextra, in Milan, Italy, uses a series of large vertical live-edge slabs of cedar wood for the display of Valextra handbags. The effect is visually dramatic; however, the persistent scent of the wood seems to be part of what makes the retail experience so memorable.[34]

While the scent of wood can evidently elicit a strong biophilic response, in most cases the scent is not necessarily perceptible or becomes imperceptible soon after the wood is installed in a space. As such, scent may be a factor in the biophilic response to wood, but is unlikely to be the predominant factor.





VISUAL EXPERIENCE

Color, collinear lines and contours are the three main visual characteristics of wood that have shown evidence of contributing to why we love wood.

Photos: courtesy Pixabay and naturallywood.com

VISUAL EXPERIENCE

While smell and touch are important senses and likely play into our overarching preference for wood, our experience of wood is most often visual; thus, it is not surprising that most of the available research on wood is related to visual response. Texture, knots, color, contrast, and other surface features of wood can influence our perception. When we look at a piece of wood, much of our attention is invested in grain pattern and surface color; and unfinished or bare wood reportedly garners more positive reactions than wood that is deeply stained.[35]

COLOR

Color is evidently an indicator of wood preference. Untreated wood tends to reflect color in the yellow to red spectrum, which is found to evoke feelings of warmth.[36, 37] In fact, this "warm" appearance has been cited by many researchers as a desirable feature of wood.[38] While there is some indication of there being cultural variations to wood color preference,[39] warmer colors hold the majority preference. It is intriguing that the preferred color range of yellow to red is said to be warm, but also calming.[40] In line with this thinking, the color of light strongly influences hormonal balance, with blueish light increasing serotonin and therefore alertness, and reddish light increasing the melatonin balance and therefore sleep.[41] On the other hand, some studies of cool and warm colors, without context of materiality, tend to indicate a different outcome. Red for example can raise blood pressure, heart rate, and aggressive behavior.[42] While these warmer, redder woods may be preferred, there is potentially another component to the visual experience of wood that is leading to the calming effect.

1077 GREAT NORTHERN WAY

The LEED Platinum office building in False Creek Flats in East Vancouver, British Columbia, features wood as structure, flooring, ceiling and handrails, to offer both visual and tactile experiences of wood without overwhelming the senses.

Architect: Proscenium Architecture + Interiors, Inc.
Photo: KK Law, courtesy naturallywood.com

GROVES AND KNOTS

The groves and knots that make up the surface pattern of wood have been the focus of a few studies suggesting a preference for wood that has a limited number of knots. Survey work indicates that a few knots are interesting, but an abundance of knots is disliked.[43] Using eye-tracking systems to study how the eye moves across an image – recording when and where the eye stops on knots – wood with many knots is shown to cause more eye stops.[44] This may mean that it takes more effort to process the what is being viewed. The researchers noticed that the introduction of parallel, colored grooves distracted attention away from the knots. This begs us to ask whether the calming and preference responses are due to the nature of wood grain itself.

GRAIN

Wood grain is essentially a series of collinear striations or patterns that are broken into segments to form nested contours. Studies with rhesus monkeys indicated that (within a given image) lines running in the same direction are processed by one set of neurons in the brain; whereas, with

ESB ATRIUM AT THE UNIVERSITY OF BRITISH COLUMBIA

The design for the mid-rise wood Earth Sciences Building at UBC uses laminated strand lumber composite floor substrate and Glulam beams and columns of Douglas Fir that elegantly hide the joints so as not to distract from the rich patterns of the exposed wood structure.

Architect: Perkins+Will
Photo: KK Law, courtesy naturallywood.com

lines running in multiple directions, more effort is needed – by multiple sets of neurons – to process the image.[45] The brain will follow curvatures and contours,[46] and even connect short segments of lines to discern a longer curving pattern.[47] These pattern conditions occur frequently in nature and our brains, it could be argued, are predisposed to easily decipher them.[48]

FRACTALS

Fractals are layered self-repeating mathematical patterns. Exact fractals, which are the result of the same equation replicated at various scales, like embedded fractal gaskets or the trippy Mandelbrot sets, don't occur in nature. However, when those mathematical patterns have variations, their ubiquity in nature becomes quite evident, such as with snowflakes, fern leaves, waves on a beach, flames in a fireplace, the dappled light under trees. These are statistical fractals—so common that when we see these patterns, even in human designed objects, it is easy for the brain to process the image and measurably lower our stress level.[49, 50] This effect is called fractal fluency.[51] While research specifically studying wood grain as a fractal was not available when writing this paper, it could

VARIABLE REFLECTANCE

Ever notice how a piece of wood can look different depending on your viewing angle? Due to the cellular structure of wood, light reflects both off the surface and penetrates into the outer cells. Light enters the cells of the wood and then is scattered back differently depending on the incident angle and on the structures inside the cell. This can make both the grain pattern and surface color appear to change. In some cases, like with tiger maple or curly koa, the effect can be almost iridescent. Fake wood does not have a cellular structure and thus far cannot replicate this visual experience.[57]

Photo: Curly Koa wood, courtesy Bill Browning

be argued that the nested contour patterns that are repeated in a wood grain fits the definition of a statistical fractal.

In Baltimore, Maryland, a study was conducted using a combination of collinear patterns and statistical fractals in carpet tiles, wallpaper, and window shades in a sixth grade mathematics classroom. The 125 students in the now 'biophilic' classroom performed better academically than students in the prior year in the same classroom, with the same teacher, teaching the same curriculum. The students and teacher reported that they felt calmer being in that classroom—responses that were supported by four months of biometric testing.[52] Could this combination of collinear patterns and statistical fractals be leading to the calming effect associated with wood in interior spaces?

WHY DO WE LOVE WOOD?

ASSOCIATIVE / SEMANTIC PROCESSING

While there is clear evidence supporting biophilic responses to olfactory and haptic experiences of wood, the predominant sensory factor appears to be the visual experience. One possible explanation for our biophilic response to wood is that the brain makes a series of associations—what is sometimes referred to as semantic processing. In other words, the brain subconsciously links wood to trees, trees to life and nature and, thus, a biophilic response is triggered.[53] This connection is somewhat implied by research on associative processing,[54] and in general public surveys.[55] It is a plausible explanation for our positive response to wood, but seems insufficient.

INTERPRETIVE PROCESSING & MASS NOUNS

How the visual cortex processes images, which are then interpreted in other parts of the brain, is an important part of the positive response to wood. One researcher has proposed that objects are sorted either by shape or by surface characteristics. The interpretive processing of an image sorts by things that can be counted (like spheres, cones, cubes, and pyramids) versus things that are a mass (like sand, water, wood). These mass objects, or "mass nouns", are processed based on surface characteristics such as texture and color (rather than form or shape).[56] When the brain looks at wood, it is (almost) instantaneously identifying the curves of the wood grain and surface appearance to determine the

"THE FOREST"

Wood grain, raw edge contours, and the naturally occurring scent of cedar satiate the senses to create an experience of refuge, calm and intrigue at Valextra's "The Forest" showroom in bustling Milan, Italy.

Architect: Kengo Kuma and Associates
Photo: SDL Studio, courtesy KKAA

type of material. Whether the object is a chair, guitar, spatula, beam, or sheet of plywood, it is identified as wood by the patterns on the surface.

If the brain relies on surface texture or pattern to identify wood, it could be another reason that unfinished or bare wood is suggested to garner more positive reactions than those that are lacquered, heavily painted or heavily stained (as lacquering the wood often changes the surface texture/appearance). That fact that wood grain is typically a collinear and contour based pattern is possibly central to the response—these collinear and contour patterns are likely easy to process, and therefore desirable.

WHEN DESIGNING WITH WOOD

The lobby fixtures and flooring at the Muji Hotel Ginza, in Tokyo, show grain really well—the occasional knots not distracting from the contour lines. The wood grain and warm color is not dominated by the dark stone. The hotel's guest room design also incorporates wood furniture and wall panels with visible grain, as part of a strategy to help ensure that travelers have a restorative experience.

Designer: UDS Ltd. for Ryohin Keikaku Co., Ltd.
Photo: Jack Zhang, courtesy Unsplash

DESIGN APPLICATIONS

When designing with wood there are several considerations for potentially maximizing the biophilic benefits of wood in our built environments.

Don't hide the grain. Choose a finish that enhances the grain pattern. Since wood is likely visually processed as a "mass noun" (i.e., based on its surface patterns) heavy painting or lacquering hides the main characteristics that distinguish it from plastic or other highly processed materials.

Prioritize grain and contour lines. Grain and contour are visually more desirable than knots. Judicious use of knots is good practice; however, too many knots can redirect visual fixation which can negate the stress reduction characteristics of the collinear and contoured patterns.

Celebrate the wood by making it readily visible. In general, having wood at around half of the surface area in a space is optimal for engendering a biophilic response. The amount of wood used on a given project may be influenced by any number of factors, but to optimize the benefit of that wood (whether in small or large quantities), think about which spaces and surfaces will be most visible. For example, in a fully fitted-out new office with furniture in place and possibly a carpet, the ceiling plane will be the most visible continuous surface; whereas, with an existing non-wood structure, the best opportunity may be as wall panels, exposed flooring or furniture; but don't underestimate the impact of small interventions, such as wood railings and door pulls.

Balance priorities. Sustainable wood sourcing is crucial for carbon accounting, habitat protection, and local economic resilience. We also want to encourage the use of sustainably sourced wood in buildings for its benefits to human health. In the design process, alongside life-cycle analyses and cost considerations, consider the long-term positive health implications of wood in material selection and application.

CLOSING THOUGHTS

Our love for wood is likely partially through association with life, partially through scent and touch, a bit through color, and largely due to the inherent patterning of wood grain. Notwithstanding this variability, the presence of wood in our built environment undoubtedly supports a biophilic experience, so let's use wood to create more restorative and convivial spaces for all. □

Adler

Ash

Aspen

Beech

Black Walnut

Douglas Fir*

Ponderosa Pine

Red Oak

Sitka Spruce

Southern Yellow Pine

Sugar Maple*

Western Hemlock

Western Red Cedar

White Birch

White Oak

White Pine

This small sampling of dimension lumber reveals great diversity in the grain, color, and fractal patterning across species.
Photos: Michael Bednar, courtesy naturallywood.com unless otherwise indicated, *courtesy Terrapin Bright Green, °courtesy Wikimedia Commons (CC0 1.0); digital reproduction of wood coloring does not necessarily accurately represent the wood species, nor does it show an accurate comparison between species.

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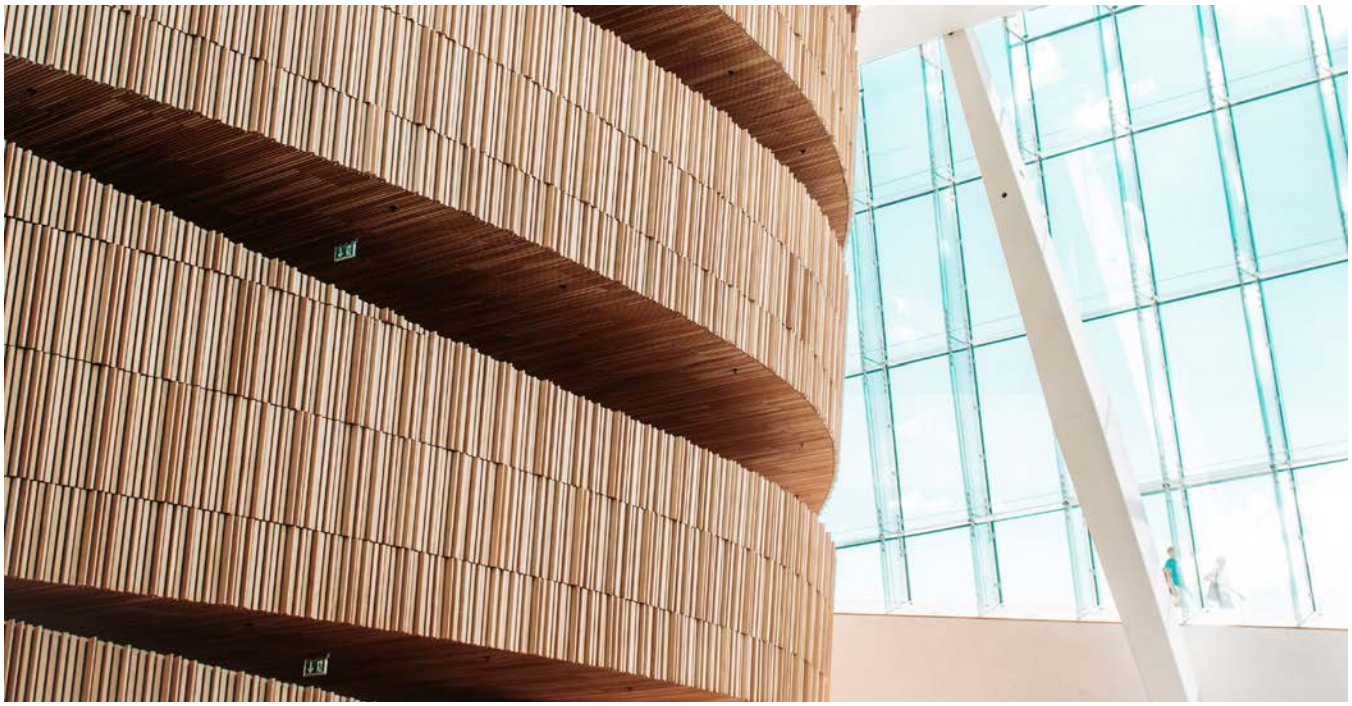
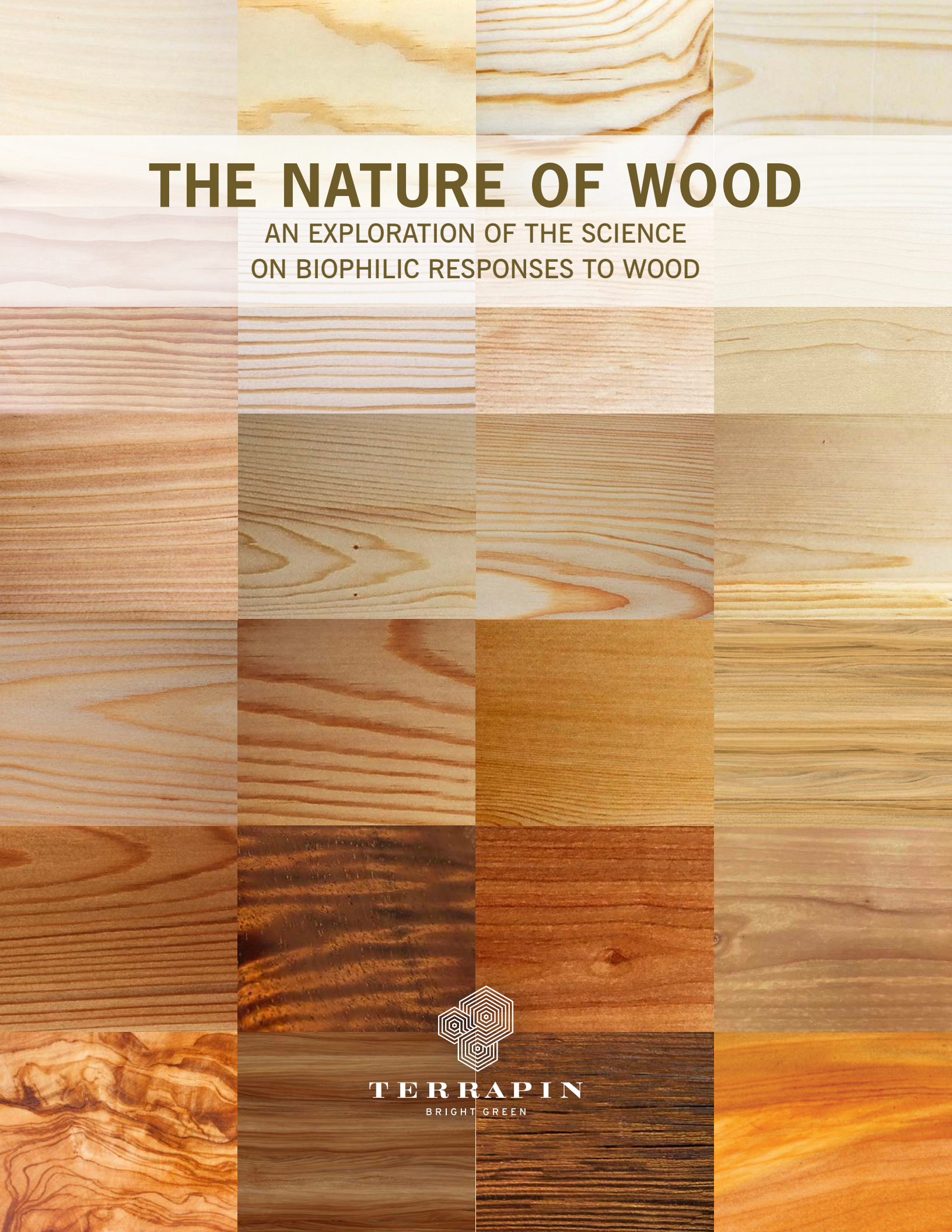


At the Oslo Opera House, the oak 'Wave Wall' designed by Norwegian boat builders is said to bring warmth to the space.

Architect: Snøhetta, Photo: Eduardo Alvarado, courtesy Unsplash


TERRAPIN
BRIGHT GREEN



THE NATURE OF WOOD

AN EXPLORATION OF THE SCIENCE ON BIOPHILIC RESPONSES TO WOOD

TERRAPIN
BRIGHT GREEN